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THE HAWAIIAN PLANTERS' RECORD

Volume XXII. JANUARY, 1920 Number 1

A monthly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

When Does it Pay to Plow?

In view of the recent comments in the annual reports of the committees of both irrigated and unirrigated plantations, suggesting that plowing and cultivating are perhaps carried on to excess, an article reprinted in this number of the *Record* is especially pertinent. It consists of a review of the literature on the tillage of the soil.

Encountering such a conflict of opinion on the subject, M. C. Sewell undertook a complete review of all the printed information on the subject. He reached the conclusion that the prevailing theories advocating deep plowing and frequent cultivation are not founded upon experimental evidence.

It will be recalled that in a contribution to the last annual report on cultivation on unirrigated plantations, Mr. David Forbes felt that "we should question our present system of deep plowing between cane rows and hilling up after a cane growth has been far advanced." He was convinced that "in many cases both are carried to extremes, and to a large extent they have become a matter of custom or routine which is hard to get away from." Mr. Forbes recognized differences in conditions that would call for variations in handling the soil, and he acknowledged benefit to ensue from certain operations.

The report on irrigated plantations also dwelt upon the matter. Offbarring, small plowing and hilling were operations open to question according to that report.

Those who will read Mr. Sewell's review of the subject and all who have anything to do with plowing or cultivating will find it extremely interesting—will very probably gain the idea that we should subject all of our tillage operations to experimental investigation.

The cost of measuring each step carefully, scientifically, will be small indeed, compared with the great gains that are in prospect should we learn that a few of our laborious and costly operations not only do not pay their way, but that they exact a further tax in actually reducing yields.

Regardless of how much or how little one may plow his lands, the thing to determine as expeditiously as possible is, when does it pay to plow?

The Cane Variety Census

The recent variety census, published as Circular 34, revealed some rather striking changes that have come about in the varieties of cane that have been adopted by the plantations.

With 20,616 acres planted to H 109, this variety becomes the standard cane for the irrigated districts. The rapid expansion of its area, crop by crop, is shown graphically in a chart which appears on the cover of this issue. The area of Lahaina is still far greater than that of H 109, but it is declining rapidly in favor of the seedling cane. The 1920 crop will include 25,078 acres of Lahaina against 7147 of H 109. The 1921 crop shows a remarkable difference in that Lahaina drops to 17,421 acres, and H 109 grows to 13,469.

D 1135 is also making rapid inroads upon the area of Striped Tip and Yellow Caledonia, although at the same time this Demerara seedling is losing ground in favor of H 109 in several of the irrigated districts.

Yellow Caledonia seems to hold its own in the district of heaviest rainfall, and still occupies an area of more than a hundred thousand acres.

There are eleven canes occupying more than 1000 acres each, counting the combined areas of the 1920 and 1921 crops. They are:

Yellow Caledonia	107,334	acres	Yellow Tip	4,728	acres
Lahaina	42,499	"	D 117	4,658	"
D 1135	23,510	"	Rose Bamboo	3,298	"
H 109	20,616	"	H 146	1,462	"
Striped Tip	5,604	"	Yellow Bamboo	1,357	"
Striped Mexican	4,938	"			

Tillage: A Review of the Literature.[1]*

By M. C. Sewell.

Introduction.

The largest item of expense in producing cereal and annual forage crops is tillage. The most important tillage operations are plowing and cultivation. Any reduction in the depth of plowing, frequency of plowing, or number of cultivations necessary for economic yields materially reduces the cost of raising the crop. The prevailing opinions are so conflicting regarding plowing and cultivation that a review of the literature seems desirable to determine what conclusions can be drawn from the written evidence on the subject.

Early History of Tillage.

The history of tillage begins with the earliest written records of mankind. Sculpturings on the ancient Egyptian pyramids represent the use of the scarcle,

* Journal of the American Society of Agronomy, Oct., 1919.

[1] Contribution No. 16, Agronomy Department, Kansas Agricultural Experiment Station, Manhattan, Kans. Received for publication June 23, 1919.

a man-power tillage implement of the chopping spade type. Other sculpturings, 4000 years old, depict a wooden plow drawn by animals.

One writer ascribes the origin of tillage to the wild boar and the observation of ancient races that plants flourished in ground previously rooted by wild boars (38).[2] The first tilling of the soil was no doubt practised in order to enable the husbandman to get his seed or plant into the soil. The second step in soil stirring was occasioned by the necessity of combating intruding weeds. The agriculture of Greece and Rome was founded on the theory that working of the soil was necessary because of the intractable soil and incursion of weeds. Virgil advocated good tillage. Since that period it has been believed that the soil is actually benefited by loosening and stirring (1).

The Early Philosophy of Tillage.

Very little seems to be known of agricultural development during the middle ages. Until 1731, when Jethro Tull published his "New Horse-Houghing Husbandry" (59), there had been no discussions of soil tillage since the time of Virgil. Tull, an English landlord, while traveling in southern Europe observed the tillage between vineyard rows. On returning to England he adapted the system to the row culture of cereal crops. He believed that the earth was the only food of plants; that the plant fed by taking in minute particles of earth, which were disengaged from the surface of the soil grains. Consequently, according to his theory, the more finely the soil was divided by tillage, the more numerous would be the particles that could be absorbed by the roots of plants. Insufficient tillage would leave the strong land with its natural pores too small and its artificial ones too large, while it would leave light land with its natural and artificial pores too large. As to weeds, he stated that they starve the plants by robbing them of their provision of food. Weeds never all come up in one year unless the land is often plowed. The best defence against these enemies, in his opinion, was a good summer fallow.

Tull ascribed the benefits of manures to the dissolving and crumbling effect they had on the soil. To this extent his theory was anti-Virgilian. According to the latter, land was pulverized by fire, and dung and harrows were used in place of the plow. The husbandry of England, especially along the southern coast, which was inhabited by Romans, was of this kind at the time of Tull's writing.

With the beginning of the nineteenth century, development in the science of agricultural chemistry through the work of Priestley (45), de Saussure (51), Davy (11), Boussingault (3), and Liebig (36), laid the foundation for the conception of the nutrition of plants as being based on the assimilation of certain chemical elements from the soil minerals, organic matter, water, and air. From this period the idea developed that tillage, by increasing the aeration of soil, increased oxidation of chemical compounds in the soil, rendering them more soluble in the soil solution.

Gaylord (18), of Onondaga, N. Y., writing in 1841, states that the end to be gained by tillage is the more effectual pulverization of the soil and mixing it together so as to insure the united action of the whole in the production of the crop. Tillage, he claims, enables us to change the character of the soil in relation to moisture, temperature, and fertility.

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[2] Figures in parentheses refer to "Literature cited," p. 17.

At a meeting of the New York Agricultural Society at Albany in 1849, Lee (35), an editor from Augusta, Ga., presented the view that exhaustion of the soil is promoted by excessive plowing and hoeing. He believed that two-thirds of the tillage in the United States, especially in the southern States, impaired the natural fertility of the soil. He attributed this to the greater oxidation of organic matter on the tilled land and to the leaching of the soil of its soluble mineral elements.

The importance of deep tillage and subsoiling was brought to the attention of the Maine Department of Agriculture by Goodale (20) in 1860. It was his opinion that these practices allowed roots to penetrate deeply in search of food and moisture. The idea that the soil contains the necessary supplies of mineral matter and that tillage operations are capable of rendering these supplies available was discussed by Goodale (21) in 1861 before the meetings of the Maine Department of Agriculture.

Tanner (57) of Ohio, writing in 1861 of the mechanical conditions of the soil favorable for the growth of seed, states that the cultivator of the soil will find in the preparation of the land for the reception of seed his most laborious duty and that which demands his greatest judgment and skill. With heavy soil he found an early preparation advisable so that it can be thrown together in a dry state after which it remains untouched until seed time.

The cultivation of field crops and preparation of soils was discussed by Turner (60) in 1866 with reference to why plowing or cultivation of the soil is beneficial. He pointed out before the Maine Department of Agriculture that the old theory that tillage increases crop production by mixing ingredients already in the soil and presenting them more readily to roots is false. Since nine-tenths of plant substance comes from the atmosphere and since the roots of wheat extends 5 feet in depth and corn roots 10 feet, scratching the surface with plows and cultivators could be of small benefit. According to his view, the real end in plowing is to put the soil in such condition that the plant may most readily absorb energy from the sun, and the moisture and other food elements from the air and soil.

The view was presented by Sweet (55) of Maine in 1871 that an important result of tillage is the control of weeds. He quotes several experiments conducted in England in which weeds reduced the crop to a large extent.

According to Johnson (26), in an address before the Connecticut Board of Agriculture in 1877, the tendencies in most soils is towards mechanical compacting and chemical petrifaction. One of the important offices of tillage, he claimed, is to counteract these tendencies. He pointed out the effect of tillage in modifying the storage of water in the soil by changing the arrangement of the soil particles. He also recognized the necessity of different treatments for different soils.

That root pruning explains in part the beneficial results of tillage was the belief of Sturtevant (54) in 1877, as expressed to the Connecticut Board of Agriculture. Experiments in which corn plants grown in water cultures and in pot cultures were pruned, showed that pruning of the roots by checking their growth stimulated seed production. Cutlivation, however, was found injurious if carried beyond the flowering stage of the plant.

Davenport (10), in discussing the preparation of the soil for cereal crops in Maine in 1881, stated that the primary object of tillage was to stir and pulverize the surface of the soil that has been hardened and packed by rains. He believed that the finer the soil the more surface there is to hold moisture and for the action of the roots, and that a well-cultivated soil seldom suffers from drouth. When wheat followed oats Davenport advocated plowing as soon as possible after harvest, and keeping the surface clean and loose thereafter.

Under Missouri conditions, Waters (63) pointed out in 1887 that sod prevents surface washing and that excessive tillage increases it. The latter condition, he believed, is brought about by rapid oxidation and decomposition of vegetable matter induced by the circulation of air in the soil as a result of the cultivation.

An English writer, Walden (61), in 1891 advocated thorough tillage and gave as his opinion that a skillful farmer requires comparatively little extra soil stimulant in the form of dung to grow a successful crop. His belief that "implements make the best manuring" is not very far from the truth.

Up to this period, literature on tillage has given only conflicting views upon the subject. From this time, experimental results were published which gave more definite information.

Preparation of Seedbeds.

Morrow and Gardner (42) of Illinois compared in 1892 the yields of corn on seedbeds plowed at depths varying from 2 to 10 inches. Their results are given in Table 1.

TABLE 1.—YIELD OF CORN FROM SEEDBEDS PLOWED TO VARIOUS DEPTHS.

Treatment, 1888 to 1893	Yield in Bushels per Acre	Treatment, 1890	Yield in Bushels per Acre
Not plowed; disked shallow.....	56.4	Plowed 2 inches deep........	54.0
Plowed 2 inches deep...........	59.9	Plowed 5 inches deep........	57.5
Plowed 4 inches deep...........	69.4	Plowed 10 inches deep........	56.0
Plowed 6 inches deep...........	69.3		
Plowed 8 inches deep...........	71.1		

None of these plots had any cultivation after planting, except removing the weeds by scraping the surface with a sharp hoe. The soil was one easily worked. It was loose, porous to considerable depth, and had great capillary attraction. They concluded that deep stirring of the soil for a crop is unnecessary and that air, water, and the roots of corn readily find their way into the soil even if it has not been stirred.

In experiments with corn at the Indiana experiment station, Latta (32) found practically no difference in yield from plots plowed 8 inches deep as compared with 4- to 4.5-inch plowing. These results were averages of yields obtained from 1886 to 1891, excluding the year 1887, when no yield was obtained. In another experiment conducted for two years, 1891-1892, there was practically no difference in the yield from plowing 6, 8, 10, and 12 inches deep. Plowing 4 to 4.5 inches gave slightly smaller yields.

The Indiana station (33) gives the average results for four years of the plowing experiments begun by Latta in 1891. These data are presented in Table 2.

TABLE 2.—AVERAGE YIELDS OF CORN PRODUCED AT THE INDIANA STATION ON LAND PLOWED TO VARIOUS DEPTHS IN THE FOUR YEARS FROM 1891 TO 1894, INCLUSIVE.

Depth of Plowing, Inches	4	6	8	10	12	14	16
Yield in bushels per acre........	33.77	34.19	35.14	34.49	35.00	34.84	34.14

According to these averages, there was a slight increase in yield with depth of plowing up to 8 inches.

Sanborn (50), in 1892, compared different depths of plowing for wheat at the Utah experiment station. A plot was also included which had not been plowed. This plot was raw sage brush land and the sage brush was cut off level with the surface without stirring the soil. The wheat was planted with a hoe and at the same depth as in the other plots. The results are incorporated in Table 3.

TABLE 3.—AVERAGE YIELDS OF WHEAT OBTAINED IN A DEPTH-OF-PLOWING EXPERIMENT AT THE UTAH STATION.

Depth of Plowing	Average Yield per Acre for Three Years	
	Grains in Bushels	Straw in Pounds
Not plowed	8.6	1013
Plowed 4 inches deep.........	14.1	1101
Plowed 6 inches deep.........	13.3	1113
Plowed 8 inches deep.........	14.7	1117
Plowed 10 inches deep.........	14.4	1317

The unplowed plot gave the lowest yield, but there was only a slight difference in the yield from the other treatments. Similar results were secured in a later experiment (49). There was, however, an increase in yield of straw with the depth of plowing.

Merrill (39) conducted experiments in which the effect of depth of plowing on the yield of dry-land wheat was compared for five years at four different branch experiment stations in Utah and at one of them for an additional two years. The yields as reported in 1910 are given in Tables 4 and 5.

TABLE 4.—AVERAGE YIELDS OF WHEAT OBTAINED IN DEPTH-OF-PLOWING EXPERIMENTS CONDUCTED ON FOUR EXPERIMENT FARMS IN UTAH DURING THE FIVE YEARS FROM 1904 TO 1908, INCLUSIVE.

Treatment	Average Yield in Bushels per Acre			
	Juab County Farm†	Washington County Farm	Tooele County Farm	Sevier County Farm
Plowed 8 inches deep	23.3	11.6	14.7	5.3
Plowed 10 inches deep	23.4	12.0	14.9	5.8
Plowed 15 inches deep	16.9	15.2	14.8	6.8
Plowed and subsoiled 18 to 20 inches deep	15.4	15.2	16.2	6.4

† Heavy clay soil.

TABLE 5.—ANNUAL AND AVERAGE YIELDS OF WHEAT OBTAINED IN TILLAGE EXPERIMENTS ON THE WASHINGTON CO., UTAH, EXPERIMENT FARM IN 1907 AND 1908.

Treatment	Yield of Wheat in Bushels per Acre		
	1907	1908	Average
Disked, not plowed	27.9	13.9	20.9
Plowed 5 inches deep	25.0	13.3	19.1
Plowed 12 inches deep, not subsoiled	29.3	26 0	27.7
Plowed 16 inches deep, not subsoiled	33.7	21.0	27.4

In Washington County the results favor deep plowing. In all others nearly as good yields were secured from 8-inch as from deeper plowing.

In experiments conducted by G. W. Waters (62) in 1893 at the Missouri station, subsoiling did not give better yields of corn than plowing 7 inches deep.

In experiments at the New York station as cited by Waters, 6-inch plowing in one experiment gave better yields than plowing 12, 18, or 24 inches deep and nearly as high yields as plowing 30 inches deep. In still another experiment 4-, 6-, and 8-inch plowing gave about the same yields, which were somewhat better than were secured from disking alone or from 2- to 4-inch plowing.

Kraus (31) decided in 1894 that the greatest influence exerted upon the production of plants is the spacing, the second the effect of manuring, and the third the depth of plowing. These conclusions were based upon experiments at Weihenstephan, Germany, in which plants were seeded in wide and in narrow rows, with manured and unmanured treatments on both shallow and deep plowing.

Wollny (67), in publications at München, Germany, in 1895, compared six treatments of the soil in field plots 4 meters square. The experiment included two plots each of three tillage treatments—unworked, plowed 18 cm. deep, and plowed 36 cm. deep, one plot of each being fertilized and one unfertilized. The fertilizer used was guano applied at the rate of 200 gm. per plot (500 kg. per hectare). The soil was a calcareous loam containing 4.5 per cent humus and 2 per cent calcium. During the four years previous to the experiment the field

had grown potatoes and had been well fertilized. The experiment was conducted for three years, the crops grown being spring rye, maize, rape, flax, peas, sugar beets, potatoes, and horse beans. Wollny concluded that loosening of the soil increased its productiveness and this increase in a majority of the cases was considerable. The increase was relatively small for rye, peas, horse beans, and flax; and was relatively large for maize, rape, sugar beets, carrots, and potatoes. The fertilizer was most effective on the deep-plowed plots. According to Czerhati (9), cited by Wollny, the increase in yield from deep plowing for oats and barley was less than for maize. Kühn was cited as having conducted experiments in which it was found that plowing a sandy soil which contained but little humus to a depth of 45 cm. produced almost as much barley as a soil plowed only 10 cm. deep.

Later experiments by Wollny included an unworked treatment with the deep and shallow working of the soil. The results obtained did not occasion any change in the conclusions drawn from the previous work.

Tancré (56), a German investigator, advocated plowing immediately after harvest. Regarding the weathering of soils, he considered the winter as the time of crumbling; the spring as the time of solubility; and the summer as the time of fermenting of manure.

In experiments at the Kansas station (19), in 1895-6, surface plowing for corn produced 34.0 bushels and subsoiling 33.4 bushels per acre.

Shepperd and Jeffrey of the North Dakota Agricultural Experiment Station (53) reported, in 1897, the average yields of wheat for two years obtained by different methods of tillage. Plowing with a disk gang plow yielded 50 pounds less per acre than plowing with a moldboard. Subsoiling gave an increase of 39 pounds per acre, but at a much greater cost. Deep plowing (8 inches deep) produced 43 pounds per acre more than shallow plowing.

Lyon (37) investigated the effect on the corn crop of deep plowing and subsoiling in Nebraska. Of 59 replies from questionnaires sent to farmers in Nebraska operating on clay subsoil, 80 per cent favored subsoiling. Of those having a loam subsoil, 23 per cent favored subsoiling. Reports from western Nebraska, where the soil and subsoil are porous, showed that subsoiling reduced the yields. In 1896 and 1897 shallow plowing (4 in. deep) both in the spring and fall gave better yields than deep plowing (8 in. deep), but disking gave lower yields than shallow plowing.

Williams (65) obtained larger yields of corn in experiments conducted at the Ohio experiment station from 1891 to 1902 by cultivating shallow than by cultivating deep. The average yields of grain were 56.4 bushels for deep cultivation and 60.4 bushels for shallow cultivation.

Farrar and Sutton (16) reported in 1906 of different depths of plowing with disk and with moldboard plows on the yield of wheat, with fertilizer and without fertilizer in New South Wales. The average yields obtained are presented in Table 6. The moldboard plow gave the highest yields in all cases. Eight-inch

plowing gave higher yields than shallower plowing in most cases, but the difference was small, probably not enough to pay the extra cost.

TABLE 6.—AVERAGE YIELDS OF WHEAT IN BUSHELS PER ACRE WITH DIFFERENT DEPTHS OF PLOWING IN NEW SOUTH WALES.

Depth of Plowing, Inches	With Fertilizer		Without Fertilizer	
	Disk Plow	Moldboard Plow	Disk Plow	Moldboard Plow
4	9.7	14.5	9.7	13.3
6	8.6	16.3	8.5	15.4
8	10.2	16.5	10.7	14.8

Reitmair (46) in 1905 compared deep plowing (27 cm. or 10.6 in. deep) with shallow plowing (15 cm. or 5.9 in. deep) for several different crops. In all cases the deep plowing produced larger yields, the difference for oats being 27.8 bushels; beans for hay, 0.22 ton; and potatoes 6.3 bushels per acre in one instance and 32.5 bushels on a duplicate plot. Reitmair points out that there was not any essential difference in the nitrate supply of the deep-plowed field compared with the other and he could not explain the wide variation in the yields of the duplicate plots of potatoes.

Kaserer (27) at Vienna, Austria, in 1906 compared plowing with the treatment of loosening the soil without plowing, on a sandy loam soil. Three plots were worked 20 cm. (7.8 in. deep) for beets with an extirpator, while two plots were plowed 20 cm. deep and left rough over winter. The two methods of preparation were also compared for wheat, barley, and corn. There was no material difference in the nitrogen content of the plots and no material difference in yield except for corn. For this crop, the results were much in favor of deep plowing.

As an average of 40 trials during a period of three years at the experiment station at Davis, Cal., Shaw (52) found an average difference of about 8 bushels of wheat and 6 bushels of barley in favor of deep plowing as compared with shallow plowing. The effect appeared to extend to the following crop, an average difference of 8 bushels in the following crop of barley being observed.

Baring (2) states that in tillage experiments in New South Wales, subpacking does not appear to increase the yield. Subsoiling and deep plowing failed to give increased yields, subsoiling apparently resulting in lower yields. The disk plow gave slightly better returns than the moldboard plow.

Noll (44) reported in 1913 on the results of three years' tests of deep (12-inch) plowing and ordinary (7.5-inch) plowing at the Pennsylvania station. The yields of corn, oats, barley, wheat, alfalfa, clover, and timothy were compared. These crops were grown in rotation. The average yields, including more recent data as yet unpublished, but kindly furnished the writer, fail to show any advantage for the deeper plowing. The average yields for 1910-1913 are presented in Table 7.

TABLE 7.—AVERAGE YIELDS OF GRAIN IN POUNDS PER ACRE OF VARIOUS CROPS UNDER VARIOUS TILLAGE METHODS AT THE PENNSYLVANIA AGRICULTURAL EXPERIMENT STATION DURING THE FOUR YEARS FROM 1910 TO 1913.

Crop	Number of Years Grown	Yields in Pounds per Acre	
		7.5-inch Plowing	12-inch Plowing
Corn	3	4128	3957
Barley	1	835	792
Oats	2	1059	1086
Wheat	2	1240	1281
Alfalfa	3	2716	2774
Clover and timothy	2	4537	4483

The draft per square foot of cross section of the furrow was determined and was found to average 1113 pounds for the 12-inch plowing and 724 pounds for the 7.5-inch plowing.

Wright (70), in 1914, reports five years' results with plowing experiments at the Oklahoma station in which 7-inch plowing gave the highest yield. There was no difference between the yields from 7-, 8-, and 9-inch plowing. Subsoiling was unprofitable. The soil was an upland silt loam with an impervious subsoil.

Williams and Welton (66), reporting in 1915, compared the average yields for deep plowing, ordinary plowing, and subsoiling for corn, oats, wheat, and clover for a period of five years. The yields are presented in Table 8.

TABLE 8.—AVERAGE YIELDS OF VARIOUS CROPS UNDER VARIOUS TILLAGE TREATMENTS AT THE OHIO AGRICULTURAL EXPERIMENT STATION IN A 5-YEAR TEST.

Crop	Treatment		
	Plowed 7.5 Inches	Plowed 15 Inches	Subsoiled
Corn (bu.)	60.69	61.12	63.01
Oats (bu.)	45.49	43.80	45.11
Wheat (bu.)†	33.14	33.37	34.18
Clover (tons)	2.43	2.35	2.34

† Average for four years only.

The results show that there is not a consistent difference in favor of deep plowing or of subsoiling.

Cardon (6), in a report on dry-land tillage experiments at Nephi, Utah, states that there was not any material difference in yields obtained from plots plowed at depths varying from 5 to 18 inches. There were eight plots employed, four being cropped each year and four fallowed. The depths of plowing for fallow were: (1) Subsoiling 18 inches; (2) subsoiling 15 inches; (3) plowing 10 inches; and (4) plowing 5 inches. Regarding soil moisture, it was found that there was no advantage in deep plowing or subsoiling, for the moisture con-

tent of the 5-inch plowing was as high as that of any of the other deeper treatments.

Chilcott and Cole (8) concluded in 1918 that, as a general practice, no increase of yields or amelioration of conditions can be expected from subsoiling or other methods of deep tillage for the Great Plains as a whole. These conclusions are based on results of extensive experiments covering a wide range of crops, soils, and conditions, in ten different States in the Great Plains. The authors very aptly sum up the function of plowing in the following statements:

It is mistaking or failing to recognize the purpose of plowing that leads to the belief that its efficiency increases with its depth even though that depth be extended below all practical limits of cost and effort. Plowing does not increase the water-holding capacity of the soil, nor the area in which roots may develop or from which the plants may obtain food. Plowing removes from the surface either green or dry material that may encumber it, provides a surface in which planting implements may cover the seed, and removes or delays the competition of weeds or plants other than those intended to grow, and in some cases by loosening and roughing the immediate surface, checks the run-off of rain water. All of these objects are accomplished as well by plowing to ordinary depths as by subsoiling, dynamiting, or deep tilling by any other method. There is little basis, therefore, for the expectation of increased yields from these practices, and the results of the experiments show that they have been generally ineffective.

Miller (41), in a study of the root systems of corn and the sorghums, isolated roots of these plants to a depth of over 6 feet and found the root development more extensive below the surface foot area of soil than above. From this fact, we may judge that deep plowing does not affect the depth of root penetration.

TABLE 9.—EFFECT OF DEPTH OF PLOWING ON YIELD IN A ROTATION OF CORN, OATS, AND WHEAT AT THE KANSAS EXPERIMENT STATION DURING THE SIX YEARS FROM 1913 TO 1918, INCLUSIVE.

Treatment	Average Yield in Bushels of Grain per Acre		
	Wheat	Corn	Oats*
Plowed July 15, 12 inches for wheat	24.6	22.1	34.7
Plowed July 15, 7 inches for wheat	24.2	24.0	37.6
Plowed July 15, 3 inches for wheat	24.9	22.9	38.2

* Average for five years, no grain yield in 1916.

Unpublished data of the Kansas Agricultural Experiment Station from the wheat seedbed rotation project do not give any appreciable differences in yields in 3-, 7-, and 12-inch plowing. These conclusions are based on the averages of six years' results. In this rotation, the wheat stubble is plowed in the fall 6 to 7 inches deep for corn, the corn stubble is disked in the spring for oats, and the oat stubble is plowed various depths for wheat. Table 9 presents the yields from this project.

The Kansas station also has eight years' results with wheat cropped continuously under different seedbed treatments. The average yields are presented in Table 10.

TABLE 10.—AVERAGE YIELDS OBTAINED FROM VARIOUS METHODS OF SEED-BED PREPARATION ON LAND CROPPED CONTINUOUSLY TO WHEAT AT THE KANSAS AGRICULTURAL EXPERIMENT STATION IN THE EIGHT YEARS FROM 1911 TO 1918, INCLUSIVE.

Treatment.	Average yield in bushels per acre.
Disked at seeding time	6.8
Plowed Sept. 15, 3 inches deep	12.7
Disked July 15, plowed Sept. 15, 7 inches deep	17.5
Disked July 15, plowed Aug. 15, 7 inches deep	18.2
Listed July 15, ridges worked down	17.5
Listed July 15, ridges split Aug. 15	17.4
Plowed July 15, 7 inches deep	20.8
Plowed Aug. 15, 7 inches deep. worked immediately	19.5
Plowed Aug. 15, 7 inches deep, not worked until Sept. 15	18.1
Plowed Sept. 15, 7 inches deep	13.5
Plowed July 15, 3 inches deep	16.4

These results show a decided benefit in the deeper early plowing (7 inches) over the shallow early plowing (3 inches) when wheat is grown continuously on the same land. Except in dry summers, the stubble on the August and September plowed plots is weedy unless it has been disked after harvest time. Moisture and nitrate determinations conducted in connection with this tillage project have led to the conclusion that early plowing is beneficial because it prevents weed growth and thus conserves available soil moisture and plant food (4).

The conclusion is drawn from the references discussed under this head that deep plowing (more than 7 inches deep) in general does not increase crop yields. The question left unsettled is the depth of plowing less than 7 inches that produces the best results and the necessary frequency of plowing that depth.

THE CULTIVATION OF CROPS.

EFFECT ON SOIL MOISTURE, NITRIFICATION, AND YIELD.

Intertillage of crops has been practised because it has been considered beneficial aside from the control of weed growth. The general belief has been that cultivation conserved moisture by maintaining a soil mulch and, by aerating the soil, developed available plant food, thus promoting bacterial and chemical changes.

Sanborn (49) found in his tillage investigations in Utah in 1893-1894, that the difference in moisture between land plowed and unplowed was 0.63 per cent in favor of the plowed.

Grandeau (22), in 1894, in discussing the advantages and effects of deep cultivation in French agriculture, stated that old tillage practices result in a lighter, better aerated soil, and that the capillary capacity of the soil is increased. These results, he believed, increased the nitrifying power of the soil, maintained the humidity of the surface soil in a more favorable condition for vegetation, and made the nutritive elements available by placing the radicles of plants closely in contact with the soil particles. Deep working during the summer was found to double the amount of water contained in the soil as compared with soil not worked.

Kraus (31), in 1894, found the results of deep and shallow working of corn and beets in Germany to favor the deep working.

Miller and Brinkley (40), in 1897, reported yields of corn at the Maryland experiment station under deep and shallow cultivation. The depths were 6 to 7 inches and 2 to 3 inches. There was a gain of 2.4 bushels in favor of deep cultivation. They state that this gain was not enough to pay for the extra cost.

Wollny (69) published an article in 1897 on the influence of the mechanical working of the soil upon its productiveness. Previous experiments at München, Germany, had shown that loosening the soil made it accessible to air and more easily saturated, but the effect of a pulverized condition had not been investigated. The crops grown in this experiment were flax, red clover, lucerne, and grass mixture. Yields were obtained four different years. The first experiments conducted in pots were verified by field plots on a clay loam soil. The plants without exception attained higher production in the crumbly soil than in the pulverized. Consequently, Wollny decided that the crumb structure characterized the condition of the soil to be striven for in a rational system of agriculture.

The effect of loosening the soil upon the nourishment contained in the soil was also investigated by Wollny (69). Crumbly and pulverized soils, fertilized and unfertilized, were compared. For fertilizer a mixture of equal parts of superphosphate, calcium chloride, and Chili saltpeter was used. The data show that the action of the fertilizer on the crumbly soil is greater than on the pulverized.

In discussing farm practices that maintain the soil in a normal condition of structure, Wollny stated that tillage should take place immediately after harvesting the crop, otherwise the loose condition of the soil is lost after the crop covering is cut and the soil exposed to atmospheric precipitation.

In answer to the question of when and how often the soil should be worked, Wollny concluded as a result of one year's experimentation that fields requiring cultivation in the spring should be plowed in the fall; that although under certain conditions repeated workings of the soil in the spring were profitable, in the spring and summer land should be worked only when in a medium degree of moisture because with a higher or less degree of moisture the crumbly condition of the soil would not result.

Wollny also conducted experiments to determine the effect of hoeing upon plant production and the relation between the effect of loosening and the destruction of weeds without cultivation. He concluded that hoeing exercises a favorable effect upon plant production practised on land loosened in the fall, but that it often proved injurious in its effect when the soil was in good mechanical condition and a long dryness simultaneously prevailed.

The comparison of the hoed and the not hoed but weeded treatments proved that the production of plants was increased through the surface loosening, but that hoeing culture attains its greatest success primarily by the destruction of weeds.

The action of fertilizers was found by Wollny to increase with the depth of the tilled stratum, fertilization with the deeper degree of tillage producing the greatest yields.

In a later publication, Wollny (68) determined the properties of coherence,

adhesion, and friction of soils. The data presented by him emphasize the advantage of the crumbly condition of the soil.

Dehérain (13), working under French conditions, compared the amount of moisture collected from drainage under the condition of vegetation compared with fallow. The average yearly percolation for three years was 417 liters from the soil without cultivation and 440 liters from the soil cultivated. He concluded that loosening the soil favors the penetration of moisture.

In 1897 Shepperd and Jeffrey (53) reported for the North Dakota Agricultural Experiment Station the average yields of wheat for two years obtained by different methods of tillage. Seeding in cultivated drills 24 inches apart produced 10.2 bushels less per acre than wheat sown in the ordinary way without cultivation. On fall plowed and spring plowed ground, there existed a slight difference in favor of shallow plowing as compared with deep.

Dehérain (14, 15), in 1900, inspired by the old proverb "two ploughings are equal to an irrigation", attempted to show experimentally why this may be true. His experiments were directed mainly to determining the effect of a soil mulch in retarding the loss of water by evaporation. Moist soil was placed in vessels which were weighed at intervals to determine the loss. A soil mulch was maintained by covering the surface with dry soil or by cultivation. The differences in the loss of moisture were insignificant in most cases, and Dehérain concluded that a soil mulch has little effect in retarding evaporation. In later experiments he found that plants growing in the soil were the principal means by which water was removed. He advanced the idea that plowing and weeding were of equal value.

Williams (65) obtained larger yields of corn in experiments conducted at the Ohio Agricultural Experiment Station from 1891 to 1902 by cultivating shallow than by cultivating deep. The average yields of grain were 56.4 bushels for deep cultivation and 60.4 bushels for shallow cultivation.

Welborn (64), in 1908, compared the yield of corn and cotton grown with deep (6-inch) and with shallow cultivation at the Texas Agricultural Experiment Station. He failed to find any advantage for deep cultivation.

Knight of the Nevada station (30) compared in 1908 the effect of mulches of different depths on checking the loss of water by evaporation. Soil containers were used, and the dry earth mulch was applied to the wetted soil. The effect is shown in Table 11.

TABLE 11.—SOIL CONTAINER EXPERIMENTS WITH MULCHES.

Depth of mulch	Water loss in inches	Percentage of the total water loss
Water surface	4.68	78.0
No mulch	1.41	23.6
3-inch mulch	.88	14.6
6-inch mulch	.36	6.0
9-inch mulch	.17	2.9

In this experiment where the mulch consisted of dry soil applied to the wetted soil, the soil mulching was effective and increased in efficiency with the

depth. However, another experiment is reported by Knight in which the soil containers were irrigated and the soil mulch established by cultivation. Compared with a water surface loss of 8.49 inches, the soil surface cultivated 6 inches in depth lost 1.09 inches of water, and the uncultivated soil, 1.51 inches. In this instance, the difference in loss is not great.

Cates and Cox (7), in 1912, tabulated the results of 125 experiments carried on for six years, 1906-1911, in 28 different States. They concluded that cultivation is not beneficial to the corn plant except in the removal of weeds.

Mosier and Gustafson (43), in 1915, showed as a result of eight years' work at the Illinois Agricultural Experiment Station that killing weeds without cultivation produced a gain of 17.1 per cent or 6.7 bushels per acre over ordinary cultivation (shallow three times).

Thom and Holtz (58) found at the Washington Agricultural Experiment Station in 1914 that tillage materially affected the amount of precipitation absorbed by the soil. With a total precipitation of 9.56 inches, land in stubble absorbed 5 inches; disked stubble absorbed 6 25 inches; and stubble disked after harvest and fall plowed absorbed 7.25 inches.

Harris and Bracken (23), reporting in 1917 on the results of soil moisture studies under irrigation similar to those reported for dry farming at the Utah station, show that cultivation was more effective in conserving moisture than pulling weeds; the difference, however, was not great. The advisability of mulching with straw as compared with cultivation eight days after water is applied hinges on the question of labor. The difference in moisture content of the soil mulched with 2 inches of straw and soil cultivated 2 inches deep was 1 per cent, and between cultivating 2 inches deep and no cultivation but with weeds pulled, was 1 per cent.

Hutcheson, Hodgson, and Wolfe (25) as a result of corn cultivation experiments at Virginia Agricultural Experiment Station, 1913-1916, concluded that cultivation of corn is advantageous. Table 12 presents their average results.

TABLE 12.—AVERAGE YIELDS OF GRAIN AND FODDER OBTAINED FROM DIFFERENT METHODS OF CULTIVATING CORN AT THE VIRGINIA STATION IN THE FIVE YEARS FROM 1913 TO 1916, INCLUSIVE.

No cultivation, weeds growing		No cultivation, weeds cut with hoe		Three cultivations		Five cultivations	
Grain, bu.	Fodder, tons	Grain, bu.	Fodder, tons	Grain, bu.	Fodder, tons	Grain, bu.	Fodder, tons
8.4	0.7	49.0	1.4	59.4	1.6	58.6	1.5

Call and Sewell (4), as a result of three years' studies with soil mulches, showed in 1917 that for silt loam types of soil with Kansas conditions, the maintenance of a soil mulch had practically no effect in reducing evaporation. It was also found that nitrate development was as extensive without cultivation as with cultivation. Later results (5), 1918, showed that cultivation by preventing weed growth conserved the soil's supply of available plant food, and that too much

emphasis had been placed on tillage as related to moisture conservation and the development of plant food.

At the Kansas station, data regarding the effect of tillage on corn yields are available for the five years from 1914 to 1918, inclusive. These results are presented in Table 13.

TABLE 13.—ANNUAL AND AVERAGE YIELDS OF CORN VARIOUSLY CULTIVATED AT THE KANSAS AGRICULTURAL EXPERIMENT STATION DURING THE FIVE YEARS FROM 1914 TO 1918, INCLUSIVE.

Cultivation treatment	Yield per acre					
	1914	1915 [a]	1916 [b]	1917 [c]	1918 [d]	Average 1914-17
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Lbs.*	*Bu.*
Ordinary	13.0	65.0	43.9	39.6	8,457	40.4
Ordinary and 1-horse cultivator to maintain mulch	13.4	62.0	43.3	39.5	8,000	39.5
Ordinary and 1-horse cultivator every 10 days	11.0	58.8	43.4	39.6	8,850	38.2
Not cultivated; weeds hoed by hand	9.2	65.0	45.2	35.0	7,580	38.6

[a] Average yield upland and bottom land, fall plowed.
[b] Average yield, fall plowed, spring plowed, and disked.
[c] Average yield, fall plowed and unplowed land.
[d] Silage yields in pounds. No grain yield in 1918.

As an average of the four years, 1914-17, the uncultivated plots where the weeds were removed produced practically as great yields as the cultivated plots. Apparently there was not any advantage from the point of yield in cultivating corn, except for the purpose of killing weeds. The small differences in yield are considered within the experimental error.

These various citations on intertillage and cultivation, with the exception of the writings of Grandeau (22) and Kraus (31) and the results at the Virginia Agricultural Experiment Station (25), show but little if any differences in the effect of cultivated and uncultivated treatments in regard to yields, conservation of moisture, and nitrification.

SOIL AERATION AND NITRIFICATION.

Concerning the viewpoint that it is necessary to promote oxidation in various chemical changes and furnish sufficient oxygen for bacterial activity, while it is recognized that oxygen is essential for chemical and bacterial changes in the soil, soils with natural drainage and in climates of medium or well-distributed precipitation may be of such a type texturally that they have sufficient aeration without cultivation practised for that particular purpose. Citations of experimental work proving this supposition have already been reviewed (5), but may with advantage be repeated in this article on tillage.

In 1902, King and Whitson (29) presented investigations at Wisconsin on

the effect of increasing aeration on nitrification. They bored holes in the soil and determined nitric nitrogen in the surrounding area. The data obtained did not indicate that nitrification was increased by this manner of aerating the soil.

In 1906, Day (12) attempted to determine experimentally the effect of artificial aeration of soils at the Ontario Agricultural College for wheat, barley, oats, and peas. The plants were grown in crocks in duplicate. Air was forced through the soil of one set once a day. There was not a benefit from the aeration of any of the crops except peas, which were very much benefited the first year. The effect of aeration on the peas was not as great the second year.

Russell and Appleyard (48), in 1915, reported results in England showing but little variation in the composition of atmospheric and soil air.

Leather (34) found that in the soils of India the diffusion of gases through soils at a depth of 12 to 15 inches is so efficient as to warrant the conclusion that cultivation of the surface soil is unnecessary for purposes of aeration. His investigations showed that even during the wettest weather, the volume of gas falls only to 15 to 20 per cent of the soil volume or about half that which is present during long periods of hot, dry weather.

Gainey and Metzler (17) of the Kansas Agricultural Experiment Station, in 1916, from laboratory studies of the rate of nitrification in a compacted and an uncompacted soil, found greater nitrification on the compacted soil up to the point where the moisture content reached two-thirds saturation.

We may judge from these various reports on aeration of the soil that many soils naturally have sufficient aeration for optimum bacterial and chemical activity without cultivation.

General Summary.

In general, we may conclude that the prevailing theories advocating deep plowing and frequent cultivation are not founded upon experimental evidence.

The review of tillage literature leads to the following conclusions:

(1) Plowing deeper than 7 inches has not generally resulted in an increase of crop yields.

(2) Shallow plowing may produce as great yields as deeper plowing, but the depth less than 7 inches which is best for economic production has not been determined.

(3) The question of frequency of plowing has not been answered, but it seems possible by proper rotation of crops to lessen the number of plowings.

(4) Cultivation may be necessary only to kill weeds and keep the soil in a receptive condition to absorb rainfall. Thus it is practical, except on very heavy soils, to reduce the amount of cultivation where the guiding policy is that of thorough cultivation in order to maintain a soil mulch.

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[J. A. V.]

Cooperation Between Field and Factory.*

By HORACE JOHNSON.

I have been asked to speak to you today on the cooperation between field and factory. More failures have been brought about by the lack of cooperation than by any other cause. Cooperation in its broadest sense means working together for some common end or object. Perhaps a better definition would be "team-work." We all know that in any game, in any business, in any manufacturing enterprise, in any community work, there must be cooperation—there must be team-work. Furthermore, in order to make a complete success of an undertaking, there must be absolute team-work between the individuals in any one section; there must be team-work between all the sections in any one department; and there must be team-work, or cooperation, between each and every department that goes to make up the whole enterprise.

The object of the plantations in these Islands is to sell for profit a raw cane sugar. To that end the total operations may be divided into two departments:

1. That of field operations, which pertain to raising and harvesting the cane.
2. That of the manufacture and marketing of the raw sugar.

The field operations may be divided into two sections:

1. *The raising of sugar cane*; which can be subdivided into—
   Plowing and preparing the fields;
   Planting;
   Cultivation;
   Irrigation;
   Fertilization.
2. *Harvesting and transporting*; which can be subdivided into—
   Cutting;
   Loading;
   Transporting;
   Weighing.

The manufacturing can be subdivided into—

First: The factory operations of expressing the juice from the cane; clarifying and concentrating the thin juice to a syrup; the further concentrating of the syrup to massecuites which are separated into sugar and molasses.

Second: The marketing of the sugar, which includes the transporting from the factory to cars or ships; the delivery to the market, and the sale of the sugar.

You field men know quite well the effect on the day's work, on the progress made, when the truckmen fail to deliver the gasoline to the caterpillar engine, and the plowing stops for an hour or so; when the ditchman turns the water into the wrong ditch, and the irrigators spend the time leaning on their hoes; when the pack train lies down in the road and the fertilizer gangs wait for fertilizer. You know the effect on the day's output in the harvesting field, the discontent

* A lecture presented at the Short Course for Plantation Men, Oct., 1919.

amongst the cutters and loaders, when the mill has a breakdown, and you don't get the empty cars back to the field; the locomotive gets off the track; a train of cars runs away; the trackmen are behind in their work of laying portable track; the flumes have to be changed, and flumes jam.

You know what effect these things have on your work, and you know how on some days there does not seem to be any cooperation or team-work anywhere, and all operations seem shot to pieces. You know and appreciate the fact that when there is cooperation in the field work, all goes well and you all endeavor to keep it so; to coordinate the work so that each operation may help and not hinder the rest.

But how can the field cooperate with the factory? It might seem that if the field raised the cane and delivered it to the factory, that it is up to the factory to make the sugar. That is true, but, nevertheless, the field can materially help the factory produce more sugar at less cost.

In order to know how this can be done, we must understand in a general way some of the operations of the factory and the conditions which limit the recovery of sugar in the process of manufacture.

In this connection, according to my observations, there is not enough desire on the part of the plantation men to know or understand the operations of the other departments with which they are not directly connected. The general attitude is "that is my work, and it is nobody else's business"; "don't butt in." Men seem to be afraid to explain their work or the reasons why certain work is carried on in a certain way. If one shows a desire to find out the reasons for certain operations, he is apt to be promptly squelched. Now, that attitude is all wrong. Unless there can be a chain of complete understanding throughout all the work, there can be no true cooperation. Any man who refuses to impart his knowledge to others, or has no desire to absorb knowledge from others, is a mighty weak link in the chain.

You are doubtless all familiar with the general process of the manufacture of raw sugar, so I will not take up time going into those details. I would like, however, to define some of the terms used in factory work, so that later on we may have a better understanding.

CANE. All that material which enters the rollers of the mill is termed cane. (It is sometimes called gross cane.) It includes all sound cane, dead cane, cane tops, field trash, dirt and water—in fact, everything that was on the car.

CANE JUICE OF NORMAL JUICE. All soluble matter in the cane is called cane juice or normal juice.

FIBER. All insoluble matter in the cane is termed fiber. This includes the insoluble matter in the clean cane, in the dead cane, in the cane tops, and in the field trash, etc.

JUICES. *Crusher or first mill juice* is the soluble matter extracted by the crusher or first mill.

Mixed juice is the juice which enters the boiling-house. It consists of juices extracted by all the mills, together with the maceration water.

Clarified juice is the mixed juice after being clarified by the action of lime and heat.

Syrup is the concentrated clarified juice, the concentration taking place in the evaporation.

Massecuite is the result of the further concentration of the syrup. This is done in the vacuum pans, and results in a mixture of sugar crystals and molasses. The sugar crystals and molasses are separated in centrifugal machines into the marketable raw sugar crystals and a molasses which still contains a considerable amount of sugar in solution.

The quality of the juices is defined by the terms of ° *Brix, polarization,* and *purity*.

The ° *Brix* represents the approximate percentage of soluble solids in the juice. The *polarization* gives the approximate percentage of sucrose in the juice. The *purity* of the juice shows the proportion of the polarization to the total soluble solids. Say we have a ° Brix, or total soluble solids, of 17.61. The polarization is 15.36. Then 15.36 is $\frac{15.36 \times 100}{17.61} = 87.2\%$, or the purity of the juice is 87.2. If the ° Brix is 17.61, and the polarization is 15.36, then there is $17.61 - 15.36 = 2.25\%$ of soluble impurities in the juice.

We have already stated that the cane is divided into soluble matter or juice and insoluble matter or fiber. If we find on analysis that the fiber is 12% of the cane, we then know that the cane consists of 88% juice. Suppose we find by analysis that the normal or cane juice has a ° Brix of 17.61, polarization of 15.36, purity of 87.2, the juice is 88% of the cane. It contains 15.36 polarization. Therefore the polarization of the cane (sometimes called the sucrose in the cane) is $15.36 \times 88\% = 13.52\%$. We now have a cane containing 13.52% polarization and a cane juice of 87.2 purity. This cane goes through the mill rollers, and a greater part of the juice is squeezed out. The fiber or insoluble matter goes through the rollers to the fire-room, carrying with it the balance of the cane juice. The greater the amount of fiber, the greater is the loss of juice.

Now let us assume that the mill is extracting 97% of the polarization in the cane sample just mentioned, which has a fiber content of 12%.

If, due to careless work in the harvesting field, there is an increased amount of field trash and cane tops adhering to the sound cane, so that we find that the cane has a fiber content of 14%, how much more sucrose or polarization is there lost than would be under normal conditions? If there are 1000 tons cane ground per day, and, under normal conditions, with 12% fiber, 97% extraction is obtained—

$13.52 \times 1000 = 135.2$ tons polarization in cane.

3% is lost with 12% fiber $= 4.06$ tons polarization lost in bagasse.

Loss with 14% fiber $=$?

1050 tons cane @ 14% fiber contains 135.2 tons polarization $= 12.876\%$ polarization.

1000 @ 12.00%	= 120	tons
50 @ 54.00%	= 27	"
1050 @ 14.00%	= 147	" fiber.

(Say 300 cane cars = 1050 tons cane; there are 333 lbs. field trash on each car.) Fiber in bagasse in both cases = 58.0%.

1st case: Bagasse = 20.69% cane = 206.9 tons, containing 4.06 tons polarization, or 1.96% polarization.

2nd case: Bagasse = 24.14% cane; 1050 × 24.14% = 253.47 tons bagasse. 253.47 tons bagasse containing 1.96% polarization = 4.97 tons polarization.

The extraction is then 96.32%, instead of 97.0%.

There is 0.91 ton more sucrose lost, which is equivalent to approximately $85 worth of sugar a day; $17,000 for a 200-day crop. This is one case where the field can help increase the yield of sugar at the factory.

FIELD TRASH IN CANE.

	I	II
Tons cane per day...........	1000 tons	1050 tons
Fiber in cane	12.00%	14.00%
Polarization in cane..........	13.52%	12.876%
Tons polarization in cane....	135.2 tons	135.2 tons
Tons bagasse	206.9 tons @ 1.96% Pol.	253.47 tons @ 1.96% Pol.
Polarization lost in bagasse..	4.06 tons	4.97 tons
Extraction	97.00%	96.32%
		Additional loss of polarization or sucrose, 0.91 ton. Available at sugar, 0.68 ton. Value @ $120: 120 × 0.68 = $81.60. For 200-day crop = $16,000 = $1.63 a ton of trash.

Another thing which vitally affects the quality of the mill and boiling-house work and the cost of production is the regularity with which the factory is run. We all know that any factory which runs continuously from Monday morning till Saturday night, will obtain a better recovery at a cheaper cost than the factory which operates on a one-shift basis only. Now, regularity and smoothness with which a factory can be operated must necessarily depend a great deal upon the condition and capacity of its equipment and the skill and attention of the operators.

Lack of equipment and breakdowns in a factory, lack of cooperation in a factory, not only react in a serious manner upon the quality of work and cost of operating the factory, but it reaches out into the field work. It backs up through the transportation system; it reaches the harvesting field directly or indirectly; affects nearly every department of the plantation. During the last few years considerable time and money have been spent in mill equipment, and every year shows increased interest, care and skill by the mill-men in the operation of their factories.

In order to run regularly, there must be an even supply of cane. No factory can do good work when it is called upon to crush 50 tons of cane for the day's

run, and slow down to 40 tons at night, and then, as it sometimes happens, runs out of cane entirely by morning. It is impossible to state the amount of loss caused by irregular, uneven crushing. It is much more than one thinks, however, unless he is familiar with factory work and has given the matter careful study. It can be stated as a fact that the fundamental basis of factory efficiency is a steady, even supply of cane, the quality being such as to comply with the normal capacity of that particular factory. This is a point which the field men must consider when coordinating their work.

When a field man is especially interested in any one field, he estimates or actually ascertains the weight of cane per acre. Then he next wants to know how the juices are running. Many times he is satisfied with the statement that the juices are good, or that they have a high density, or maybe a good purity, but not much sugar. You hear all these expressions quite commonly, but they really do not convey much meaning as to the quality of cane. Let us take the same example of cane as we previously used—a cane having 13.52% polarization, and a cane juice of 17.61° Brix, 15.36 polarization, 87.2 purity.

The *polarization of the cane* and the *purity of the juice* are the controlling factors in the quality of that cane. Either one alone does not mean much. We might have a cane of high sucrose and high purity, giving a very high yield of sugar. Another cane having the same percentage of polarization but of low purity will not yield nearly as much sugar. Again, another cane of high purity, but low percentage of polarization, will, of course, yield a smaller amount of sugar. In order to arrive at the quality of the cane, we must embody these two varying factors into one expression. The term now commonly used is the number of tons of cane required to produce a ton of sugar. This is also expressed as the quality ratio.

If a field man knows the amount of cane per acre, and then finds out from the factory the quality of that cane in terms of tons cane per ton of sugar, or the quality ratio of that cane, he can at once know the approximate yield of sugar per acre or the actual value of the field.

You have noticed that the Experiment Station, in reporting the results of their field experiments, give the weight of the cane, the quality ratio, and the tons sugar per acre. This quality ratio is determined from the analysis of juice and a formula for recovery of sugar from that juice.

$$\text{Tons cane per ton of sugar} = \frac{1.00}{0.8 \text{ poln. in juice} \left(1.4 - \dfrac{40}{\text{Purity of juice}}\right)}$$

This formula does not take into consideration variation in fiber content of the cane, nor the actual quality of the factory work. However, tables have been made from this formula, and it is therefore very simple to determine a comparative quality ratio from the juice analysis only. This table is used at many plantations for arriving at the quality of cane from the different fields. Other plantations have made up tables of their own, which take into consideration the quality of work done by that particular factory. These tables probably come closer to the actual quality of the cane than the results obtained by the H. S. P. A. tables.

Either method, however, can be used, as the results by any one method are strictly comparable.

We have previously stated that the polarization of the cane and the purity of the juice are the controlling factors in limiting the recovery of sugar. Now let us see how *much* effect the purity of the juice has on limiting the recovery of sugar. In a general sense the purity of the juice does not affect the extraction of juice by the mill. The limiting effect is in the boiling-house work.

We previously assumed a cane having 13.52% polarization and a cane juice of 87.2 purity. After clarification, this juice would have a purity of approximately 88.7. Such a cane, with good factory work, would produce a ton of sugar for each 7.83 tons of cane. 100 tons of cane would yield 12.771 tons of sugar.

(° Brix of cane, 15.50; polarization of cane, 13.52; impurities, 1.98%.

Yield of sugar, 12.771; yield of sucrose = 12.324; sucrose lost, 1.196.

$\frac{1.196}{1.98} = 51.$ 100 impurities prevents 51 sucrose from being recovered.)

Now let us assume a cane of 13.52% polarization, and a purity of juice after clarification 85.7. With the same quality of factory work, this cane will have a quality ratio of 8.03, and 100 tons of cane will yield 12.453 tons of sugar. 12.771 — 12.453 = 0.318, or 2.50% less sugar than was obtained in the first case. This loss is due to the impurities in the juice, which prevent the sugar from crystallizing. Roughly speaking, each unit of soluble impurities in the cane presents 0.50 of a unit of sugar from crystallizing. The more impurities, the greater the loss in sugar.

As cane ripens, we find less of the soluble impurities which come under the head of glucose, and an increase in the amount of polarization. Under these conditions, where we might have an unripe cane having a juice of 18.32° Brix, 15.7 polarization, and 85.7 purity, and polarization of cane 13.82%, quality ratio of 7.74, which upon further ripening would produce a juice of 18.32° Brix —16.12—88.0 purity, and assuming the same fiber as above, this cane would then have 14.19 polarization in cane, and the quality ratio would be 7.40.

7.74 tons cane @ ton sugar	= 12.920	tons sugar @ 100 cane
7.40 " " " " "	= 13.501	" " " " "
	0.581	" gain = 4.50%

As a rule, an increase in the purity of the juice means an increase in the polarization of the cane; the two together mean a material increase in the yield of sugar. Barring climatic conditions, what can be done in the cultivation, in irrigation or fertilization of cane, to increase its purity? On an irrigated plantation, is it good practice to keep the water on the cane right up to harvesting time? What is the right time to take it off? In fertilization, is it good practice to put on nitrates too late in the season? What is too late? Any conditions relating to the purity of the cane juice can be studied to advantage by the field men.

With the present price of sugar, an increase in purity of one degree would mean, on a 20,000-ton crop, an increase of 400 tons of sugar, valued at $48,000.

If, due to late harvesting, the cane is overripe, or, as we say, "goes back," then we would lose sugar in the proportion as we have shown above. A drop in purity not only means that we have narrowed the limits of recovery in the boiling-house, but that we have lost some of the original sucrose as well. This can be illustrated by the following table:

Cane Juice			Poln. % Cane	Tons Cane per Ton Sugar	Sugar per 100 Cane	Gain or Loss
° Brix	Poln.	Purity				
18.00	15.84	88.0	13.94	7.52	13.30	+ 6.4%
18.00	15.66	87.0	13.78	7.67	13.04	+ 4.3%
18.00	15.48	86.0	13.62	7.83	12.77	+ 2.2%
18.00	15.30	85.0	13.46	8.00	12.50	0 0
18.00	15.12	84.0	13.30	8.16	12.25	— 2.0%
18.00	14.94	83.0	13.15	8.32	12.02	— 3.9%
18.00	14.76	82.0	12.99	8.49	11.78	— 5.8%

Prof. Dean, in one of his lectures on plant life, showed us how the plant takes in CO_2 through its leaves, water through the root system, and, by the aid of light and heat, transformed these elements into the hextoses

$$3\ CO_2 + 6\ H_2O = C_6H_{12}O_6 + 6O$$

In cane sugar we call the hextose compounds, glucose. A further reaction goes on within the plant which changes the hextose or glucose to sugar.

$$2\ C_6H_{12}O_6 = C_{12}H_{22}O_{11} + H_2O$$

glucose = cane sugar.

These actions are going on simultaneously, so that we always have glucose and sugar present in the cane. In the unripe cane there is a relatively large amount of glucose and a small amount of sugar. As the cane ripens we find less glucose and more sugar. When the cane is over-ripe or starts "going back," we find the reverse taking place—the amount of sugar decreases and the amount of glucose increases.

	Unripe Cane	Ripe Cane
Cane juice:		
° Brix	18.32	18.32
Polarization	15.7	16.12
Purity	85.7	88.0
Fiber % cane	12.0	12.0
Polarization % cane	13.82	14.19
Quality ratio	7.74	7.40
Sugar per 100 tons cane	12.920	13.501
Gain	....	0.581 ton
Gain	....	4.50%

Doubtless you have read in the September number of the *Record* the article on "The Deterioration of Cane After Cutting." The results are surprising to everyone.

According to the tests made, there is a loss in weight of 2% for each of the first three days after cutting, and from then on the loss in weight is 1 to 1.5%.

1 day old	2.0%	4 days old	7.0%
2 days "	3.9%	5 " "	8.5%
3 " "	5.5%	6 " "	9.7%

Taken by itself the loss in weight would not be material, for if at the same time there was no destruction of sucrose, the amount of available sugar would be the same. Unfortunately there is a destruction of sucrose, and to a much greater extent than we have realized. The experiments show a loss of available sugar of

1 day old	2.5%	4 days old	18.5%
2 days "	5.0%	5 " "	23.0%
3 " "	12.5%	6 " "	27.5%

Experiments were conducted with different cane varieties. The losses of D 1135 were the greatest. Then followed Lahaina, and H 109 seemed to show the least deterioration. The Experiment Station made no tests on Yellow Caledonia, but tests made at some of the plantations show that this cane lost at about the same rate as the average shown of the above-mentioned varieties.

"It is realized that the figures given are for a few deteriorations only, and that the rate of deterioration is not necessarily the same under other conditions. However, as the losses indicated by even a short delay in grinding the cane after cutting are so serious, and are corroborated by other tests made in other countries, we should make a study of this situation.

"Tests should be made on as many plantations, and under as widely varying conditions, as possible. The Experiment Station is willing to cooperate with any plantations planning to conduct such tests, and will render any assistance possible."

Just how much loss is actually sustained by the plantation is hard to estimate. We all know that in most places some of the cane is ground one day after the cutting, a part of it gets to the mill in two days, more in three days, and some in four days or longer.

As each car of cane is not sampled and analyzed separately, we might not notice the variations in the quality of the cane from the different cars. The juice is analyzed, say, in four or six-hour periods. The average sample of these periods might not vary much, while there might be big variations in the individual cars.

Now it is commonly considered that if one gets the cane to the mill within three days after cutting there is no loss. According to the tests which have been made, the loss amounts to 7.5% more than if the cane was crushed two days after cutting.

On a 20,000-ton crop this would amount to 1500 tons of sugar, at present valued at $180,000. Now, these figures seem appalling, yet there is every indication of their being at least approximately correct.

We cultivate, irrigate, fertilize an acre of cane for 500 days at a cost of, say, $150 per acre. By delay in getting that cane to the mill we can lose in three days sugar to the value of $80 an acre. We concentrate on methods of cultivation, experiment with kinds of fertilizer, to reduce costs and increase yields. Yet with three days' delay in getting the cane through the mill we can lose three-quarters of a ton of sugar per acre.

To be consistent we surely should study this phase of the plantation operations, and make every effort to reduce this possible loss.

Fertilizers and Soils.*

By S. S. PECK.

The purpose of this paper is to explain something of the nature and functions of fertilizers as applied to sugar cane. In order to understand the question of fertilizers, it is necessary to know something of the nature and peculiarities of the soil, which will be treated briefly.

It is not necessary to enlarge on the importance of the subject. Every member of a plantation staff is eager to get as much sugar per acre as possible; and more cane means more sugar, provided the extra cane is not produced at the cost of the quality of the juice. The factories are striving mightily to get more and more sugar into the bags from the cane delivered by the field men, by increasing the extraction at the mills and diminishing the losses in molasses. An increase of 2 per cent in extraction is viewed with considerable satisfaction, and certainly reflects credit on those responsible. But this 2 per cent is not all velvet; it is obtained sometimes at the cost of extra fuel, or of expensive milling machinery, of breaking rollers or new boiling-house installations, but it *pays*. Now, sugar is made in the first instance in the field. If a field produced 50 tons of cane per acre, yielding 6 tons of sugar, and the yield is increased to slightly over 51 tons with 6.12 tons of sugar, it has jumped up 2 per cent, but one would probably never notice it. But if the yield jumps up to 55 tons cane, with 6.6 tons of sugar, or a gain of 10 per cent, then the field men begin to take notice and pat themselves on their respective backs. And if the yield drops that much, then they begin to ask questions or, what is worse, have questions asked of them.

When the number of sticks of cane on an acre of land is considered, it is remarkable how a little change one way or another makes for an increase or decrease in crop. Thus: On an acre of land are 50 tons of cane with stalks averaging 8 feet in length, 1.2 inches in diameter, and weighing 12 ounces per foot or 6 pounds per stalk. If the length of each stalk is increased 10 per cent, the average length of stalk now being 8 feet 10 inches, the yield is likewise increased 10 per cent. But if the diameter is increased 10 per cent, or by twelve one-hundredths of an inch, the yield goes up 21 per cent. And if both increases transpire, the yield increases 33 per cent, or from 50 to 66 tons cane per acre. Again, if the crop is producing five sticks to the stool, and one can force or wish another stick of equal weight and size on each stool, the yield increases 27 per cent, or to 63 tons of cane. In other words, and working backwards, to get an extra 2 per cent in the field, one need only either increase the average length of the stalk from 8 to 8.16 feet, or by 2 inches (and here the importance of careful attention to the work of the cutting gang might be mentioned), or the average diameter from 1.2 to 1.212 inches; or in place of having five canes to a stool, force one stool in every ten to have six canes. It would be a hard matter to notice an extra 2 inches in the length of stalk; or that one stool in

* Presented at the Seventeenth Annual Meeting of the Hawaiian Chemists' Association.

every ten was producing one more stalk than the other nine; and 12 thousandths of an inch increase in diameter would require very careful and painstaking observations. Yet any one of them would mean 2 per cent more sugar produced. But we are not concerned nor must we be satisfied with such slight advantages. What we must be after is: first, big crops; second, bigger crops; and third, biggest crops. We cannot all have the last, but we should aim for it, and then we can at least make a hit at the second.

The cane grows in soil. Soil is not a dead, inert mass of dirt. It is the home of millions of living organisms and the seat of constant and numberless chemical changes. There is much that we do not know about it; there is also much that we think we know, but wherein we are probably entirely wrong. Every soil presents its own peculiar problems, many of which can be answered only by the man on the job. We do know that the soil is the house, as it might be called, of the crop. And the crop, to be robust and healthy, requires that its house should be as wholesome, from a crop standpoint, as ours. It must be sanitary; well aerated; the plumbing or drainage must be efficient; it must be free of pests; and lastly, but not leastly, the larder must be well provisioned. Not only plentifully stocked, but the stuff must be of the right kind. Each crop, besides, requires its own peculiar ration. Just as a hog and a canary differ both in kind and quantity of food consumed, so do plants. But of paramount importance is the cleanliness of the quarters. All crops respond to efficient tillage, which is their house-cleaning. That is essential. If one gave an animal most liberal rations, but allowed its quarters to become filthy, one could expect nothing but disappointment in its progeny. So in the cane; no matter how well or how liberally it is fertilized, unless the soil is in good tilth, there will be no compensating returns. At the inception of experiment station work on the mainland there were many farmers who thought that all that was necessary to produce bumper crops was to get a small bag of soil—the smaller the better, as it cost less postage,—mail it to their State experiment station, where a soil doctor would analyze it and send back a recommendation for fertilizer. Then Mr. Farmer would buy a ton or so of Clover Leaf brand, or Diamond Q fertilizer, curtail his cultural operations, and think that the arduous work of harrowing or plowing could be replaced by the easier operation of scattering about some bonemeal or chemicals. It would be like one of us feeding up on lobster a la Newburg when our stomachs were not in shape to digest a milk shake.

The fertilizers or food can now be discussed. There are natural fertilizers, like stable or pen manure, the virtues of which are too well known to require repetition. Then there are the artificial fertilizers, which supply plant-food materials in a more concentrated form. The requirement of crops for nourishment is today largely supplied by such materials. Each part of human or animal food plays a definite role in the economy of the body—replaces worn-out tissues, builds up new tissues, supplies muscular energy or nerve force, etc. So in plant life, each fertilizer element or ingredient has its function. Some of the food of humans acts, not as a direct food, but as a stimulant. It might perhaps be added that much of that drank acts similarly. So it is in the plant: some fertilizers act not as direct food, and they are called indirect fertilizers. We all know that some stimulants, if used too freely, are no longer helpful. So in the

plant, an excess of these indirect fertilizers may work more harm than good. The food of humans has to go through a course of preparation in the various digestive organs to transform it into a shape fit for the body. So in the plant, the fertilizer ingredients are changed according to the need and nature of the particular crop. And to complete the comparison, the great necessity for human life is respiration; we draw in air and expel gaseous waste; the plant, too, is breathing, drawing in gases from the atmosphere and expelling what it doesn't want.

Now, what is the source of this artificial plant food or fertilizer? It was not so many years ago that plantations fertilized with nothing but bone-meal; and to this day the old plantation Oriental calls the expensive high-grade fertilizer bone-meal. It is now recognized that bone-meal alone is not a properly balanced ration for cane. It is very rich in phosphoric acid, with a far less amount of nitrogen. Numerous experiments have demonstrated that cane requires more nitrogen than phosphoric acid; the bone-meal was doing good to the extent of its nitrogen content, while most of the phosphoric acid was performing no useful service, but was nevertheless paid for. It was like feeding some children a slab of bread and honey, with lots less honey than bread. The kid simply licks off the honey and the bread is not consumed—not that in this instance the bread would not prove a better food to the infant than the honey, but he just doesn't want it; just as the cane doesn't want so much phosphoric acid but is just crazy about nitrogen.

The mixed fertilizer now applied to cane is composed of three essential elements—nitrogen, phosphoric acid, and potash.

Nitrogen. The fertilizer guarantee usually states a percentage of nitrogen, with certain proportions as nitrate, as sulfate, or as organic. Nitrate nitrogen is supplied as soda, coming from Chile, whence the name Chile saltpeter, and contains 15.5 per cent of actual nitrogen. This nitrogen is accepted as being directly available; that is, the plant takes it up directly and through its digestive processes transforms it into plant tissue or life. Not only is it used in mixed fertilizers, but it is also applied alone in extra dressings. It is very soluble in water and is not fixed by the soil, so can be applied in irrigation water. The expression "fixed" requires an explanation. Those who operate automobiles know that gasoline is freed of water by straining it through a chamois skin. The water is "fixed" (temporarily) by the chamois. Soils possess the property of fixing or holding onto certain elements or combination of elements; nitrate of soda is not so held, at least as regards the nitrogen part. For this reason a heavy rainfall after a nitrate application is liable to wash part of it below and away from the reach of the plant mouths or roots, and it will be lost.

Nitrogen as sulfate means nitrogen in sulfate of ammonia. Ordinary ammonia is a chemical combination of nitrogen with three parts of another element, hydrogen. Fourteen parts by weight of nitrogen form seventeen parts of ammonia. Ammonia is a gas, as one realizes when putting his nose over a bottle of strong ammonia water. The principal source of the gas is in the products of dry distillation, as in making coke or bone-char. The gas is led into sulfuric acid, with which it combines, forming the non-volatile sulfate of ammonia; this is recovered by evaporation and crystallization like sugar or salt.

Sulfuric acid is used because of its cheapness and the good handling properties of the resulting salt.

Organic nitrogen comes principally as the end products of the slaughter-house, as blood, tankage, or bone; or as the concentrated offal from fish industries as fish-scrap. In addition, vegetable residues like cotton-seed meal and castor pomace are valuable sources of organic nitrogen, but are rarely if ever seen here. Blood is the most concentrated form, containing up to 14 per cent of nitrogen; tankage and fish-scrap come next; while bone, as before stated, contains a small amount, generally from three to four per cent. Another product, hoof-meal, with over 10 per cent, is sometimes found in mixtures, but unless it is well prepared is not very available.

In addition to these forms of nitrogen, there is still another and very important supply. The air about us contains 80 per cent of nitrogen in the free state, which certain favored plants can make use of. Unfortunately, sugar cane is not in this category. On an average, cane is given about 150 pounds of nitrogen per acre per crop. Yet an acre of soil a foot deep contains about 6000 pounds of nitrogen in organic form, and the air above this acre contains 71,000,000 pounds, yet 150 pounds of combined nitrogen in fertilizers makes a marvelous difference in crops (sometimes). This means that the cane demands its nitrogen properly prepared, just as men and animals do, and just as most plants do. Certain plants, amongst which the more familiar are clover, alfalfa, and beans, can take their nitrogen from the air and store it in little swellings on the roots. They use this nitrogen for themselves or it can be used for another crop when the gathering crop is harvested or turned under. It is like the honey bee. The bee stores up the sweets it gathers so industriously from the flowers, and then men or a big brown bear comes along and reaps the benefit. And just as the honey will not accumulate in the hive alone without the assistance of the active little bee, so the nitrogen must be gathered from the air through activity of a living organism, in this case bacteria. Without the presence of these minute organisms these plants would, like all other plants, live on the nitrogen they find in the soil or die of nitrogen starvation. Some soils are populated with these organisms; others must be inoculated, which can be done either by introducing some soil known to be inhabited or by artificial cultures. The first is the more successful, but has the same objection as our immigration problems —some or a great many undesirables may be brought along with the desirables, and these undesirables may be not only loafers, but criminals. Again, like the busy bee, granting that the beneficial organisms are in the soil, if nitrogenous fertilizers are used, the host plant develops a lazy streak and gets its nitrogen therefrom with the least exertion on its part; very much like the bee, which, if supplied with sugar and water near the hive, may not go to the painstaking effort of working the flowers. This is a form of graft that even humans are occasionally guilty of. So if cane is planted along with one of these plants, known as leguminous plants, and nitrogenous fertilizer is applied, the chances are that instead of benefiting the cane, it is being robbed of just the amount of nitrogen gobbled up by Mr. Jack Bean or whatever legume is used.

There is yet another organism which plays a part in gathering nitrogen from the air, and it doesn't need any plant to help it either. It goes by the name

of azotobacter, which means nitrogen bacteria. These little fellows are like their cousins, however, in that they will not work unless they have to. In a field growing cane and receiving fertilizer they are rather inactive; but when a field is fallowed, and particularly when it receives an occasional cultivation during fallowing, these bacteria take nitrogen from the air and enrich the soil to an extent that is sometimes surprising; this nitrogen is in a state that becomes readily available to the cane, and explains in part the benefit obtained from resting a field.

By the term "availability" of nitrogen is meant that condition in which it can be taken up by the roots of a plant and utilized. There can be but little doubt as to the availability of nitrate nitrogen. The effect of a nitrate of soda application is quickly apparent in the appearance of the leaves of the cane. So it is generally accepted that nitrogen to be available must be in the form of nitrate of some sort. It is not the soda, since nitrate of lime does equally well, and nitrate of ammonia would be still better, but is too expensive. Nitrate of soda is not fixed or held by the soil. Sulfate of ammonia is held very firmly. If a solution of sulfate of ammonia is poured on a column of soil a foot deep and the drainage collected, no ammonia will be found therein. Under favorable conditions, ammonia is changed in the soil to a nitrate combination, by a species of bacteria. There is no need to worry about the presence of these microbes—they are in all good soils of good tilth. They do their work better under certain conditions, the principal ones being good drainage and aeration and the presence of lime. These bugs work slowly, so that the nitrate is formed gradually and not subject to waste like it is when applied directly as such, at least to a far less extent; for it must be remembered that as soon as the transformation is complete, the new combination is no longer fixed by the soil, but subject to loss by leaching, and it is also available. Organic nitrogen is practically insoluble in water, so naturally is not liable to loss by leaching, neither is it available. The nitrogen in it is transformed by a different regiment of bacteria into ammonia, which is then grabbed by the other species just referred to and changed into the nitrate form. The advantage of having several forms of nitrogen in a mixed fertilizer is now apparent. The nitrate form is at once available to the crop; by the time it is used up by the plant or by leaching, the sulfate of ammonia is being turned into nitrate and starts feeding the cane; then follows first the ammonification and then the nitrification of the organic nitrogen. It is a sort of relay banquet offered to the cane, and at the cost of but one application the nitrogen nourishment is furnished in palatable form for a long period of time. The cost of the nitrogen varies according to its origin, the nitrate being the cheapest and the organic the dearest. It might be asked, why not use only nitrate and put it on at intervals during the entire crop in the irrigation water? The pulp of the grape is a pretty good food, but the skin and seeds are rather indigestible. If one were to devour a lot of them, skins, seeds, and all, he would be getting the food value of the pulp, but would be accumulating a lot of trouble from the rest, which may crop out as indigestion or appendicitis. So in nitrate of soda: the cane takes up the nitrate but leaves a corresponding amount of soda in the soil. This soda if it accumulates does damage to the soil in proportion to the amount present. The black alkali soils

in the States owe their condition to the soda salts present. On the other hand, when sulfate of ammonia is used, the ammonia only is consumed and sulfuric acid released. Soda and sulfuric acid may be compared to the positive and negative poles of a battery, one neutralizes the other, and from the combination there is thus less danger of harming the soil. The danger from either source would arise only when large doses were given the soil, but the effect may be cumulative, and this is the reason that some plantations occasionally replace the extra nitrate dressings with one of sulfate of ammonia with very good results. One point more in regard to sulfate of ammonia; it nitrifies very much better in a soil well supplied with some form of lime, which is one reason why putting on coral sand tends to increase crop yields.

Phosphoric Acid. The two principal sources of this are bone and phosphate rock. In both the acid exists in the same combination, but seems more available in the bone probably for this reason: bone contains organic nitrogen, and when it is stirred into the soil and supplied with sufficient moisture, this starts to putrefy, which is one of the stages of ammonification already referred to. In this process certain gases are given off which help to dissolve the phosphate portion of the bone. This point is important, for it is only when in solution in the soil water that the mineral nutrients are absorbed by the root hairs of the plant. The soil is full of decaying organisms and plants, so that there is always more or less of gas being generated, depending on conditions, one of which is a correct amount of moisture; for all this decomposition is effected by living organisms, and they must have water just as do all the higher forms of animal life, or die. The gas is principally carbon dioxide, the same gas which when compressed into syphons gives such an agreeable "pep" to grape juice and other extinct drinks, and helps us to solve many difficult problems. So in the soil it helps dissolve and make available to the plant insoluble materials like bone or phosphate rock. This explains why bone is more easily available than rock, and why the latter is rendered more available if plowed under with a green crop. As a rule on these Islands, phosphoric acid is supplied in a form known as "water-soluble," which means just what it says. This form is prepared by treating phosphate rock with sulfuric acid, when there is a chemical change effected and the phosphoric acid becomes soluble in water. It is known then as superphosphate or acid phosphate. Being soluble in water it has the advantage over other forms of being well distributed in the soil. It is not carried away by drainage, being fixed very rapidly; but now, instead of being in fairly large particles, it is distributed in a very fine state on the particles of soil, and more easily attacked by the soil water and acids. An intermediate form of phosphate is that known as reverted phosphate. While not soluble in water, it is quickly dissolved by weak acids, and appears to be a very desirable form under certain conditions. Plants cannot survive in the absence of phosphoric acid, and it is just as essential to the organisms of the soil, without which there would be no crop. So whether the argument is that phosphoric acid is used as a part of the fertilizing system as food for the crop or as food for the organisms, the answer is the same. The United States is fortunate in having large deposits of phosphate rock and cheap sources of sulfuric acid.

Potash. As the name indicates, this was first obtained from the burning of wood, the ash remaining under the cooking utensils. Today the main supply is in some favored parts of Europe. It is mined principally as the chloride, but on account of better handling properties, as well as the reluctance to put any more chlorine compounds in our soil water than is already supplied by the salt therein, it has usually been purchased for Island purposes in the form of sulfate. Both salts are soluble in water, and the potash part is fixed by the soil. It is a fact that most of the Island soils are well stocked with potash, but the extent to which this is available is problematical. Large amounts are removed by the crop. The molasses from the factories, large amounts of which are shipped away, contain about 4 per cent. If an acre produces 50 tons of cane, on the basis of 2.8 parts molasses per 100 cane, this may mean 112 pounds of potash, which is already quite in excess of the 70 pounds which were formerly applied when potash was obtainable. An acre foot of soil contains from 8 to 14 thousand pounds of potash. The latter would be sufficient for 100 crops; but, as already stated, it is not certain how available it is.

In conclusion, it may be interesting to note the regular cycle which is or can be followed by the fertilizer elements. Thus phosphoric acid is applied to the soil; some of it is held there, some of it is taken up by the crop, and a very small proportion is taken out in the drainage waters and eventually finds its way to the sea. Of that taken up by the crops, some is fed to animals, the bulk of which goes into the formation of bone, and the bones are again put on the land in the form of bone-meal. Or man is the consumer and a part follows the sanitary arrangements back to the sea, where it is consumed by the finny inhabitants, which starts the cycle again through the human route or directly by application to the soil as fish-scrap. The cane takes up some which may be divided into the part which remains in the bagasse and trash, and that in the juice. The last is precipitated out during clarification, is recovered in the mud or press-cake, and goes back to the soil. The potash cycle is not so evident, as most of that consumed is voided and the return not so rapid. All vegetation contains it as a considerable proportion of its ash or mineral matter. What is contained in the cane leaves is returned to the land when the cane is burned or the trash turned under; that in the juice finds its way into the molasses and could be, and is in some places, almost entirely conserved by burning the molasses and saving the ash; or if the molasses is fermented for alcohol production, the potash is in the residue and can be recovered. If the molasses is run into the irrigation water the potash naturally finds its way back to the soil, but there are objections to putting molasses on growing cane. The closing of the European sources of potash during the war has been an incentive to investigations into possibilities of local production; the most promising of these in the United States were certain kelps on the Pacific Coast, and the brines from some salt lakes.

The nitrogen cycle is both more complicated and interesting. It is shown diagrammatically in this diagram taken from the 1909 Year Book of the U. S. Department of Agriculture.

Imagine that all the nitrogen originally in the world existed as the free nitrogen of the air, as shown in the inner circle. This is useless to most crops,

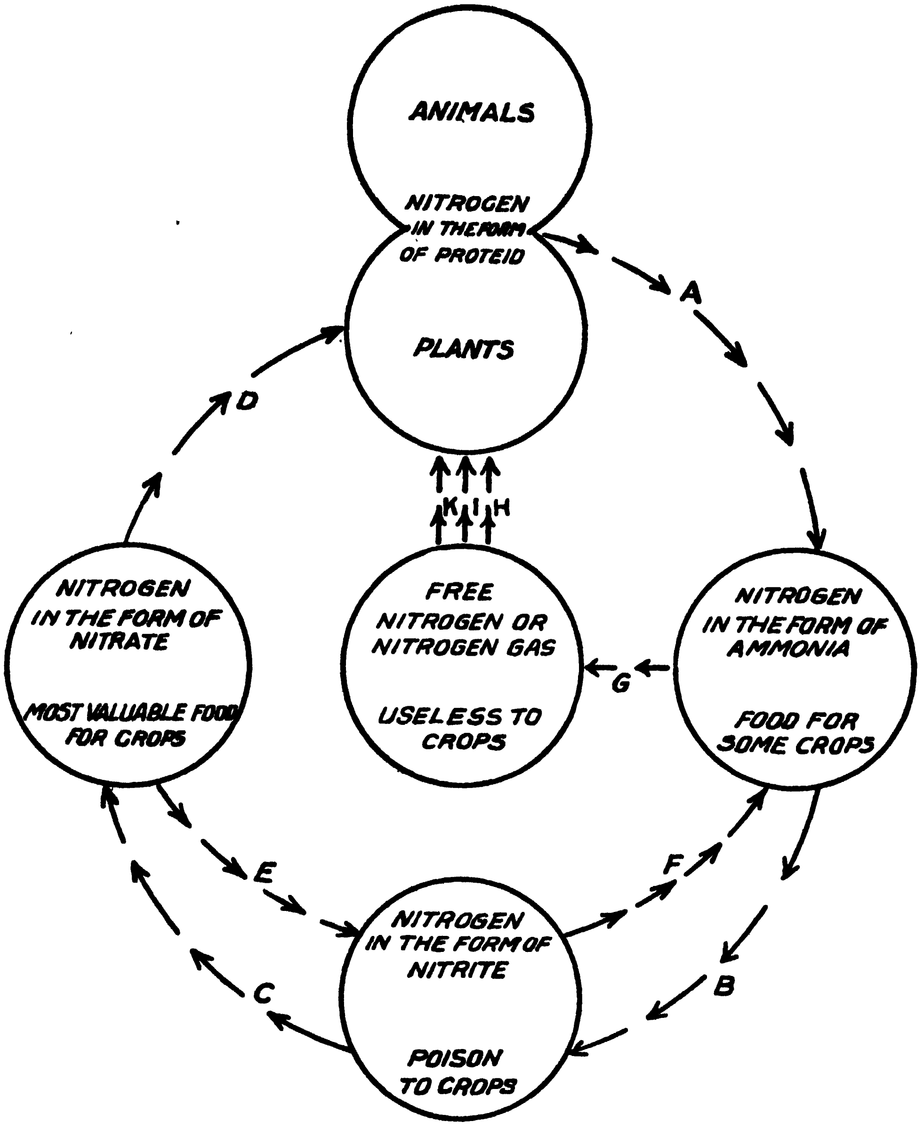

Diagram showing the nitrogen changes produced in the soil by the action of bacteria. The arrows indicate the course of the changes which various groups of bacteria may produce in the nitrogen compounds of the soil. A, action of ammonifying bacteria which change organic nitrogen to ammonia; B, action of nitrifying bacteria which change ammonia to nitrite; C, action of nitrifying bacteria which change nitrite to nitrate; D, assimilation of nitrate by green plants; E, action of denitrifying bacteria which change nitrate to nitrite; F, action of denitrifying bacteria which change nitrite to ammonia; G, action of denitrifying bacteria which change ammonia to nitrogen gas; H, action of bacteria which change nitrogen gas into proteid nitrogen; I, action of bacteria which in symbiosis with leguminous plants change nitrogen gas into proteid nitrogen; K, action of bacteria which in symbiosis with certain non-leguminous plants change nitrogen gas into proteid nitrogen.

but, as already explained, it can be transformed by the action of certain microorganisms into a form suitable for future use by plants, this form being known as proteid. Animals eat the protein of the plants, and the upper circle is shown as a part of the protein circle. If this nitrogen-holding material is buried, be it animal or plant, it decomposes into ammonia nitrogen, following the line "A." Some plants can use it as such, but generally it suffers a further change along

line "B" into the nitrite form. This combination is poisonous to plant life. Fortunately, it does not remain long as such, nor does it accumulate in good soils, but changes along line "C" into the nitrate form where it is plant food, along line "D" back into the proteid form in plants, ready again for nourishment of animals or directly for another cycle through the series. All of the nitrogen is not conserved in this way. There exists a tribe of destructive organisms in the soil which break down what the beneficial organisms build up, and some of the nitrate nitrogen may be decomposed back through the series into free nitrogen, as indicated by lines "E," "F," and "G," or even by a short cut directly back to the form of free nitrogen. This does not occur to any extent in well-drained and well-aerated soils, and is generally the result of poor husbandry.

Finally, the question of proper fertilization of cane has not yet been completely answered. There are so many varying conditions entering, as soil, climate, water supply, variety of cane, etc., that no set rule will suffice. The plot experiments now being conducted by our Experiment Station are throwing much light on the subject, and close observation with exchange of experiences will materially assist in putting this subject on a more definite basis.

Some Results From the Use of Phosphoric Fertilizers at the Haiku Substation.*

By F. G. KRAUSS.

As agricultural chemists, you are familiar with the general properties and functions of phosphorous as a fertilizer constituent. It may be interesting to some of you, to have illustrated, by concrete examples, some of the remarkable results obtained from its use, in its various commercial forms as fertilizer, on a variety of agricultural crops in this Territory.

Our upland soils at Haiku, on the northern slopes of Haleakala, with an average annual rainfall of about 70 inches, are very unproductive in their virgin state to most agricultural crops other than pineapples. The natural growth on most of these lands is guava and a rank growth of Hilo grass, and the lands are quite acid. In texture they would be classed as gravelly loam. The surface soil is 12 inches in depth on an average, and the natural drainage is fairly good.

With the best of tillage and most seasonable planting, very poor results are obtained from planting corn, beans, potatoes, etc., and it is impossible to get a stand of alfalfa, although some of the ranker-growing legumes, such as pigeon peas, do fairly well.

* Presented at the Seventeenth Annual Meeting of the Hawaiian Chemists' Association.

The following analysis will give a comprehensive insight into their chemical composition:

ANALYSIS OF TYPICAL NEW ERA HOMESTEAD SOILS AND THEIR ACCOMPANYING SUBSOILS.

Haiku Substation.

A—Soil No. 591 (plot 13-14, section E, division 1): Soil that has proved best for pineapples.

B—Soil No. 593 (plot 7, section C, division 1)—Soil that has proved poorest for pineapples.

Chemical Analysis	Soil "A"		Soil "B"	
	0"-12" Surface Soil	12"-24" Subsoil	0"-12" Surface Soil	12"-24" Subsoil
Insoluble matter	34.25	40.30	41.55	37.35
Soluble silica	....	....	....	....
Potash (K_2O)	0.01	0.01	0.03	0.05
Soda (Na_2O)	0.58	0.50	0.15	0.22
Lime (CaO)	0.21	0.18	0.29	0 28
Magnesia (MgO)	0.70	1.18	0.78	0.47
Br. ox. of manganese	0.18	0.06	0.41	0.18
Peroxide of iron	34.22	33.12	35.95	36.32
Alumina (Al_2O_3)	15.55	11.20	8.43	10.95
Titanium (TiO_2)	5.02	6.01	5.00	4.05
Phosphoric acid (P_2O_5)	0.052	0.16	0.34	0.36
Sulphuric acid (SO_3)	0.36	0.44	0.29	0.22
Carbonic acid (CO_2)	....	....	....	....
Volatile matter	9.39	9.24	8.46	9.85
Nitrogen in soil	0.254	0.139	0.152	0.223
Hydroscopic moisture	2.59	2.43	2.16	3.58

From the above it will be seen that these soils are low in their content of potash and lime, in both the A and B samples, which were taken from adjacent fields, and as noted, one producing good and the other poor pineapples.

The A sample is low in phosphates, but the B sample would be classed as high in this constituent. The nitrogen content is high, as it is in most of our soils, and the iron very high, as compared with other standards.

Complete fertilizers were formulated on the basis of these analyses. The soil was first given a heavy application of lime, the caustic and hydrated forms being used equal to 2 tons of the oxide per acre, disked into the surface six inches. The complete fertilizer, made up of 4% nitrogen in equal parts of sodium nitrate and ammonium sulfate; 8% potash as sulfate; and 8% phosphate made up of equal parts super-(acid) phosphate and reverted. This was applied in the drill at the rate of 500 and 1000 pounds respectively per acre at time of planting. In very few cases were the gains in yields over the unfertilized plots sufficient to pay the cost of this high-priced fertilization. Heavy green manuring was practiced throughout the several years during which these experiments were under way,

and while the general average of our yields kept on improving, the returns were inadequate to the outlay.

In 1916 a comprehensive fertilizer experiment was undertaken on a plan essentially embodying the principle laid down in the "Triangular" scheme of fertilization. Every commercial form of the three so-called essential elements entered into our first comparative test of fertilization materials. The results were most astonishing. Only the phosphates, and these in every form used, i. e., as double super, super, as reverted, as Thomas' slag (basic slag) and as very finely ground bone meal gave us any results worth while. The lowest increase in yield from the use of 250 pounds as a minimum and 500 pounds as a maximum of either superphosphate or reverted phosphate per acre, was on Yuba cane (forage cane), which gave 80% increase. On Maui Red and Navy beans the increased yield from such fertilization has exceeded 500%, check plots yielding an average of 395 pounds prime bean seed per acre, and the fertilized plots 2100 pounds per acre. The money value represented by these yields is as $23.70 is to $126. The outlay in fertilizers in this case was 250 pounds superphosphate at $26 per ton, plus cost of application.

Innumerable experiments on corn have given us increased yields of from 200% to 400%. Potatoes have yielded 100% to 300% increase. Alfalfa could absolutely not be grown until the phosphatic fertilizers were applied. No single crop has failed to respond to even small applications of phosphoric acid, and on lands that originally failed to produce as much corn as the seed planted in the ground, have been made to produce the banner corn crop of Hawaii, a hundred bushels of shelled corn per acre.

Soil Solution.*

By WM. WEINRICH.

In reviewing the literature on soil analysis and in reading over the prevalent theories concerning the way plants are fed or sustained by what they take from the soil, there seems to me to be a lack of co-ordination between the great principles involved. At one time it was considered that if we knew what the soil contained in the line of plant food, we would be in a position to amend or supply any deficient element. Apparently this is not wholly true. There seems to be an additional phase of the matter which I believe can be explained by the study of the nature and properties of the soil solution.

Let us review the methods used in soil analysis. *One method for indicating the available plant food present in the soil is that of the digestion of the soil by a strong mineral acid, usually hydrochloric, which is supposed to dissolve out of the soil about the same amount of material as the plant is supposed to use. The

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other method is that of the digestion of the soil by a weak organic acid. Originally espartic acid was used, but later a one per cent solution of citric acid. Both of these acid methods have points of value and some points of doubtful value. The acid digestion methods are supposed to simulate the condition that exists around the root.

It is a well-established fact that most plants can assimilate food from the soil only through their root system, and this root system must be immersed in its soil solution. If this statement be true—and there is ample evidence to support it—it would therefore be highly desirable to analyze not only the soil, but its soil solution. What do we understand by soil solution? Let us define it. According to Cameron, "A soil solution is a natural nutrient medium from which the plants absorb the mineral constituents which have been shown to be absolutely essential to their continued existence and development."

The study of soil solution dates back quite a number of years, during which time various investigators have tried to devise methods which would give the true soil solution for chemical analysis, but most of them have failed because of the very minute amounts of the soil solution obtained and the attenuated form in which it is delivered.

Methods Involved for Extracting the Soil Solution.

Perhaps the first method that seemed promising was that of Doctor Lipman of the University of California, who subjected soil, held in a strong container, to the maximum pressure of some 53,000 pounds to the square inch. Contrary to belief, this tremendous pressure yielded but a very small amount of soil solution. An important factor, which at that time was overlooked, was that this tremendous pressure changed the rate of solubility of the various elements entering into the soil solution, such as specific gravity, surface tension, viscosity, osmotic pressure and specific conductivity; hence this method does not give the true index of the soil solution as it exists in its natural state.

Another method that at one time looked promising for obtaining a soil solution or water film from the soil particle, was that of whirling a mass of soil in a centrifugal separator. This did not prove out, as it was shown later that the force necessary to separate the water film from the soil particle was much greater than the force developed by a centrifugal going at the rate of 8000 revolutions per minute. Of course, this water film must not be confused with the capillary water which is easily separated by the method just outlined.

It was Lord Rayleigh who demonstrated mathematically that the force holding the film of moisture on the soil particle was of considerable magnitude, this order of magnitude being from 6000 to 25,000 atmospheres.

Several other methods later developed, namely, the method of drainage, the method of soil extracts, the artificial root method, and, lastly, the displacement method.

This paper wishes to emphasize the modified displacement method, the displacing material being an inert paraffine oil. Some of the earliest materials used were water and alcohol. Later Van Shutelen and Itano devised a method by which oil was used. A modification or improvement of this method was devised by Morgan of the Michigan Agricultural College, who used pressure

instead of suction for forcing the oil through the compacted soil. Morgan's method is somewhat as follows: A heavy steel cylinder, having a diameter of about 6 inches and a length of about 22 inches, is used to hold the soil. This cylinder is threaded at both ends to receive caps, the bottom cap being fitted with an outlet pipe and a heavy copper and asbestos screen to prevent the soil from passing through when the oil pressure is applied; the top cap having an inlet pipe through which the oil is delivered to the top of the soil. The inside of the cylinder is perfectly smooth and has a polished surface, for the reason that any tool marks or scratches would allow the oil to follow these as channels whereby the oil would pass through without coming into contact with the soil particle. When an extraction is to be made, the soil is tightly packed in the cylinder and the top cap screwed on. An inert paraffine oil is then applied to the top of the soil through the agency of the hydraulic pump, this hydraulic pump exerting a pressure of about 500 pounds to the square inch. What apparently takes place is that the paraffine oil is forced into the soil and wedges or cleaves the water film from the oil particle, pushing the water film ahead of itself. In the course of from 10 to 24 hours, depending upon the texture of the soil, the resulting soil solution is allowed to drain out from the bottom of this cylinder, which, to all intents and purposes, delivers a true representation of the soil solution which surrounds the soil particle. It has been demonstrated by Mr. Morgan that the various physical constants such as surface tension, viscosity, specific gravity, etc., are not in any way changed from their true state by this low-pressure method of extraction.

The essential feature of this method is that a very large percentage of soil solution present in the soil is delivered at the outlet of the cylinder. In some cases as high as 70 per cent of the soil water is extracted and rendered available for analysis, or to be used for a nutrient solution for the growth of plants. I believe the results of this method, combined with the results of our standard method of soil analysis, will give more nearly the true condition which takes place in plant growth than we have been able to obtain heretofore.

This preliminary data is presented as a possible aid to those who have soil problems, and it is hoped that this will be supplemented during the next year by actual figures from our Hawaiian soils.

How to Get Reliable Results from Experiments.*

By W. P. Alexander.

INTRODUCTION.

DEFINITION: A field experiment is a practical test in the field in an endeavor to ascertain and compare the relative value of different agricultural practices.

FUNCTION: A field experiment aims to answer specific plantation questions that demand more than observations. It should furnish data that can be used practically to increase profits as well as yields. The results of properly conducted field tests, continued over many years, are not theory, but proven facts—facts that are guide-posts to efficiency, and that eliminate all guess-work.

VALUE: A field experiment is valuable only when properly planned, correctly laid out, carefully conducted, and the data obtained accurately recorded and properly interpreted. Unless these details are thoroughly worked out, a field experiment is not only worthless, but is a dangerous thing. False results might mislead and cause great losses before the error was detected. Accuracy and extreme care are necessities of all field experimentation.

EXPERIMENT TECHNIQUE.

PLANNING AN EXPERIMENT: In the beginning one should analyze the questions asked, deciding:

(1) *The object of the experiment.* Let it be as simple as possible. Eliminate all factors that might confuse final results. During the two years or more, in which time the experiment is to run, we must not deviate from our initial purpose. Once *decided,* stick to the project without change through as many seasons as possible. The experiment must be worth while ten years from now, just as well as at the present date, if it is worth conducting at all. The curse of successful experimentation is the failure to follow an object through many years, come what may. Therefore, have the object one that will stand the test of time.

(2) *The comparisons to be made.* Let these also be as simple as possible. Follow the principle that definite results can only be obtained when the factors involved can be readily interpreted without consideration of any theory involved; that actual yields of the different treatments will be the sole method of drawing conclusions. Therefore, have as the proposed comparison some standard, proven practice against some unknown or doubtful practice. Always check up and correlate one plot treatment with another.

SELECTION OF SITE OF EXPERIMENT: If there were no variation in soil fertility, field experiments would not be a difficult task. However, there is no experimental field that has uniform conditions throughout its entire area. Select the site of an experiment, with due regard for the uncontrollable factors preventing uniformity of plots, taking into consideration: (a) Soil—chemical,

*A lecture presented at the Short Course for Plantation Men, October, 1919.

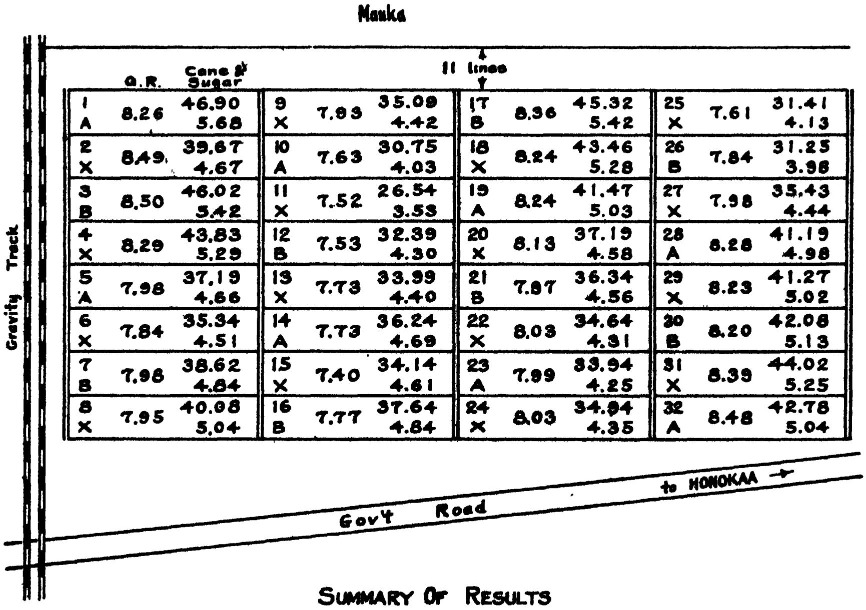
physical, and biological variations; (b) Unevenness in drainage; (c) Exposure to wind. Try and find a site where the topography is as uniform as possible. This does not mean find the most fertile spot, but find the location where all plots will be subject to the same conditions.

ARRANGEMENT OF PLOTS: It is now a recognized principle of field experiments that there be many small plots, and that they be repeated again and again, scattering the plots over the entire experimental area, until each treatment has been tried out under the varying conditions of soil fertility. The law of averages is made use of. The result is that the *repetition of plots* has partly eliminated the error due to discrepancies in soil variation, moisture changes, and wind effect.

The arrangement of these repeated plots may be done in different ways, depending on the kind of experiment, and the area given to the test.

REVERTED PHOSPHATE EXPERIMENT

PAAUHAU SUGAR PLANTATION CO. EXP. 12, 1919 Crop



Plot	Q.R.	Cane & Sugar	Plot	Q.R.	Cane & Sugar	Plot	Q.R.	Cane & Sugar	Plot	Q.R.	Cane & Sugar
1 A	8.26	46.90 5.68	9 X	7.93	35.09 4.42	17 B	8.36	45.32 5.42	25 X	7.61	31.41 4.13
2 X	8.49	39.67 4.67	10 A	7.63	30.75 4.03	18 X	8.24	43.46 5.28	26 B	7.84	31.25 3.98
3 B	8.50	46.02 5.42	11 X	7.52	26.54 3.53	19 A	8.24	41.47 5.03	27 X	7.98	35.43 4.44
4 X	8.29	43.83 5.29	12 B	7.53	32.39 4.30	20 X	8.13	37.19 4.58	28 A	8.28	41.19 4.98
5 A	7.98	37.19 4.66	13 X	7.73	33.99 4.40	21 B	7.87	36.34 4.56	29 X	8.23	41.27 5.02
6 X	7.84	35.34 4.51	14 A	7.73	36.24 4.69	22 X	8.03	34.64 4.31	30 B	8.20	42.08 5.13
7 B	7.98	38.62 4.84	15 X	7.40	34.14 4.61	23 A	7.99	33.94 4.25	31 X	8.39	44.02 5.25
8 X	7.95	40.08 5.04	16 B	7.77	37.64 4.84	24 X	8.03	34.94 4.35	32 A	8.48	42.78 5.04

SUMMARY OF RESULTS

Plots	No. of Plots	Treatment	Yield Per Acre		
			Cane	Q.R.	Sugar
X	16	No Reverted Phosphate	36.94	8.01	4.61
A	8	750# Reverted Phosphate	38.81	8.09	4.80
B	8	1500# Reverted Phosphate	38.71	8.04	4.81

Example of layout having "every other plot a check."

(1) *Every other plot a check.* This layout is of value, (a) when the topography is irregular, and when the point to be determined is very fine; (b) when trying to prove or disprove a practice that has long been established; (c) when we wish direct comparisons, and (d) when we have a large experimental field, and the area is not restricted.

(2) *Every third plot a check.* Advisable when, (a) area is restricted; (b) topography is even, and (c) differences between plot treatments are greater.

(3) *Series of plots.* This arrangement can be used when there is a very

Mixed Fertilizer vs. Nitrate of Soda
Hakalau Plantation Co. Exp. #2, 1919 Crop

Plot	Treatment	Cane	Sugar
1	A	38.57	4.55
2	B	39.71	4.94
3	C	42.82	5.24
4	A	37.18	4.39
5	B	39.18	4.87
6	C	32.35	5.18
7	A	38.97	4.60
8	B	41.47	5.16
9	C	43.81	5.36
10	A	36.73	4.34
11	B	40.69	5.06
12	C	41.98	5.14
13	A	37.30	4.40
14	B	38.10	4.74
15	C	40.05	4.90
16	A	35.13	4.15
17	B	39.40	4.90
18	C	38.47	4.71
19	A	37.61	4.44
20	B	33.99	4.23
21	C	37.28	4.56
22	A	33.39	3.94
23	B	35.71	4.44
24	C	41.04	5.02

Hilo side — Field Road — 3' path — Honokaa side — 25' — 174'

Mauka

Field 31 A

1st ratoons, long

24 plots — each 1/8 acre consisting of 5 furrows. Each furrow = 5' wide & 174' long.

Example of layout arranging the plots in a series.

uniform field, and the experiment deals with a subject requiring the determination of relative values, as varying amounts of fertilizer. When the plots are placed in series form there must be many repetitions. When more than five plots are used to a series, the distance between plots of the same treatment becomes too great for accurate comparisons. Three or four give more satisfactory results.

(4) *Checker-board system.* This lay-out has become standard on plantations where the experimental area is of sufficient length and breadth, i. e., in the form of a square. It can be used in combination with the above arrangements of

plots. It will be seen how accuracy in plot comparisons can be obtained. Every "B" plot, for instance, is adjacent, and under approximately the same conditions as the surrounding "A," "C" and "D" plots. Under some conditions this form of experiment cannot be laid out, but in country not divided by gulches, this system gives the best results.

Mud Press Experiment

Paauhau Sugar Plantation Co. Exp. 13, 1919 Crop

Mauka

Old Gov't Road — Honokaa →

Cane & Sugar

1 A Discarded	6 B 37.68 4.49	11 C 47.43 5.56	16 D 49.68 5.93	21 E 45.68 5.27	26 A Discarded
2 B 36.93 4.55	7 C 36.80 4.48	12 D 39.68 4.67	17 E 44.68 5.36	22 A 35.43 4.41	27 B 42.05 5.11
3 C 39.50 4.93	8 D 36.18 4.31	13 E 39.25 4.63	18 A 35.93 4.33	23 B 30.43 3.79	28 C 46.93 5.64
4 D 36.80 4.41	9 E 39.75 4.69	14 A 38.80 4.87	19 B 37.68 4.73	24 C 38.43 4.81	29 D 38.30 4.64
5 E 37.75 4.47	10 A 32.75 4.18	15 B 38.55 4.69	20 C 30.18 3.66	25 D 44.43 5.32	30 E 42.18 5.00

3' Path & furrow

Gov't Road — To Honokaa →

Summary Of Results.

Plots	No. of Plots	Treatment	Yield Per Acre		
			Cane	Q.R.	Sugar
A	6	No Mud Press	35.73	8.03	4.45
B	6	1 ton Mud Press	37.22	8.16	4.56
C	6	5 tons Mud Press	39.88	8.22	4.85
D	6	10 tons Mud Press	40.84	8.37	4.88
E	6	15 tons Mud Press	41.55	8.48	4.90

Example of layout using the "checker-board system."

SIZE OF PLOTS: Experience has shown that to get reliable results plots should not be smaller than 1/20 acre, nor larger than 1/4 acre. The American Society of Agronomists in 1918 asked all experiment stations, "What do you consider the ideal size of plots?" The majority favored 1/10 and 1/20-acre plots. Numerous tests have demonstrated that a plot of 1/10 acre lends itself best to conditions where sugar-cane culture is under investigation. On many plantations it is very difficult to obtain a uniform set of plots of over 1/10 acre

each. Smaller and larger plots, it has been proven, increase experimental error. In the computation of results, and the application of specific treatments, it is very convenient to have a 1/10-acre plot.

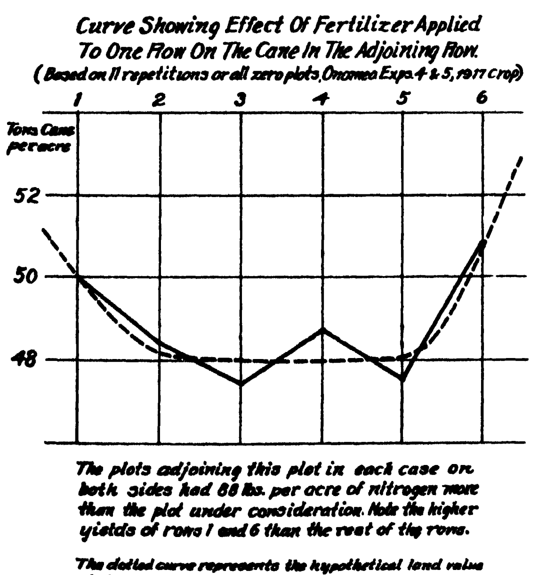
NUMBER OF ROWS TO A PLOT: This is decided by conditions met with on a plantation. Given irrigated conditions, the distance between watercourses lends itself very readily to a 1/10-acre plot composed of 8 or 10 rows consisting of two watercourses in length, or double the number of rows and one watercourse in length.

On an unirrigated plantation a plot of less than six rows is unsatisfactory. When the land is irregular, six rows make a very good standard plot of about 130 feet in length. Thus a flume line down the middle gives a distance to pack the cut cane a little less than the standard 75 feet.

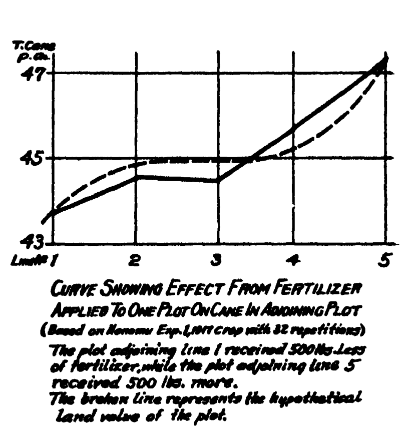
It is very essential that there be an even number of lines, as it is common practice when harvesting for the cane-cutters to work in pairs and tie the cane cut from two lines in one bundle. An odd line causes much confusion.

NEED OF GUARD ROWS: The influence of the treatment of one plot upon the adjacent plot is often very great. To overcome this factor, we may use the two outside rows of each plot to protect the remainder. The following example shows what a safeguard such lines are:

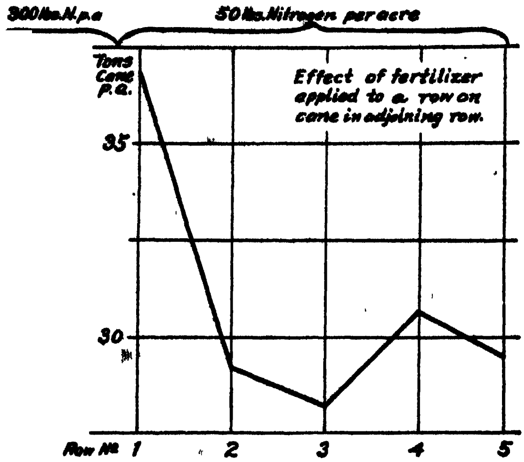
A study of the effect of fertilizer applied to one line upon the cane in the adjoining one was obtained when the line weights were kept separate in Honomu Experiment No. 1 (1917 crop). A decided influence of the heavily fertilized row over the adjacent less heavily fertilized row was found varying from 2.9% to 25%, depending on the degree of difference in the fertilization between two lines.



This curve shows the effect of fertilizer applied to one line on the cane in the adjoining line. In this case the errors at both ends of the plot are in same direction.



Showing effect from fertilizer applied to one line on cane the adjoining line. The errors are in opposite directions and therefore compensated.



This figure is based on five no-fertilizer plots in Honomu Experiment 1 (1917 Crop). The plot adjoining line 1 in each case received 2500 lbs. fertilizer per acre more than the plot under consideration. The curve shows the striking effect of this fertilizer on the adjoining line, No. 1 of the next plot.

RELATION OF SITE TO HARVESTING PRACTICE: When laying out an experiment, consideration must be taken of the harvesting practice. Unless it is decided where the portable track or flume line will be located at the time of harvesting, complications result. Ease in harvesting not only facilitates the work, but lessens the chance for error. Conform to plantation routine if possible. To do this requires much thought when the experiment is laid out.

Having each plot contain straight lines which run the full length of the plot is an essential of experiment layout that must not be overlooked. There is nothing that causes more trouble when harvesting than the so-called "hapas" or half lines. They should be eliminated from all experiments.

MARKING THE EXPERIMENTAL AREA: An experiment when laid out must be so well marked and separated from the rest of the field that it will be impossible for ignorant laborers to interfere with the plot treatments. The expenditure of much time and money can be instantly lost if a gang fertilizing the surrounding field enters an experiment dealing with fertilizer practice. The following precautions should be taken:

(1) *Information.* (a) Overseers should be provided with detail maps. Full knowledge of the details of the experiment stimulates their interest so that they take a personal concern in seeing that the experiment is protected, and its welfare looked after.

(b) A point should be made to carefully explain to the laborers working in the field just where and what the "try cane" is.

(2) *Demarkation.* (a) Unirrigated Plantations:—The rear boundary can be marked by a wire fence or small stakes placed in the bottom of each row after cultivation has been completed. A small trail 2 to 3 feet wide will suffice until the cane grows large.

(b) Irrigated Plantations:—Level ditches, straight ditches, and water-courses form the natural boundaries. In both cases all experiment corners should be well marked with iron pins or good-sized fence posts. The planting of two different varieties in an experiment so as to form a natural division of plots has been found to simplify the marking of plot boundaries.

Signs and front-line stakes are very important to so mark the different plots that there is complete information in the field as to the situation of each plot and

treatment. A map should be prepared showing layout and should include nearby roads, fences, etc., for reference. It is not enough to have the experiment well mapped on paper. The location must be well marked out in the field.

CONDUCTING AN EXPERIMENT.

UNIFORM TREATMENT OF PLOTS: Conclusions from experiments must be based with absolute certainty upon yields due to the changed condition which is artificially imposed. If the experiment deals with fertilizer, there must be a uniformity of all other agricultural practices, such as: preparation of the land for planting, selection of seed cane, planting, irrigation, and cultivation; the only variation being in the kind and the amounts of fertilizer applied.

Preparation for planting. Special care must be taken when plowing, harrowing, and mould boarding that each operation is carried out in such a manner that the plots when ready for planting differ in no respect as regards drainage, depth of plowing, and condition of the seed bed.

Selection and planting of seed. It is very important that all plots be planted with seed of identical nature. Healthy cuttings must be obtained from cane of the same age and vigor. When planting, an equal number of seed should be placed in each row. Replanting must be done until a uniform stand is secured.

Irrigation. Attention must be given to see that all plots receive water in constant quantities.

Fertilization. Only by weighing the fertilizer separately for each plot and applying it line by line can it be evenly distributed. Experienced men must be provided to make the application very uniform. A sample of all fertilizer used should be obtained and placed in an air-tight bottle to be analyzed for its formula.

Cultivation. For all cultural operations, such as hoeing and mule work, no one plot should receive advantages over another.

HARVESTING: The cutting, weighing, and sampling of the cane must be performed with the utmost care and accuracy if the results are to have any value. This requires vigilant supervision and more time than is ordinarily given to field harvesting.

Cutting. The cane from each plot must be thrown or bundled together, and so segregated that there is no opportunity for error. It is a good plan to place the brightest and most intelligent cutters on the boundary lines, where the real chances of mix-up occur.

Weighing. Where portable track is used, the cane from each plot is loaded on separate cars, and weighed at the mill. Don't fill cars so full that cane is liable to drop off. Where the practice is to weigh by bundles in the field, if the experimental area is small every bundle should be weighed. This is often impractical, and investigation has shown that weighing every third bundle gives results that are fairly accurate.

Sampling. The most satisfactory sample is one that is taken of the crusher or first-mill juice. By switching together cars from plots of like treatment, and unloading them on the carrier consecutively, there is obtained a flow of cane from

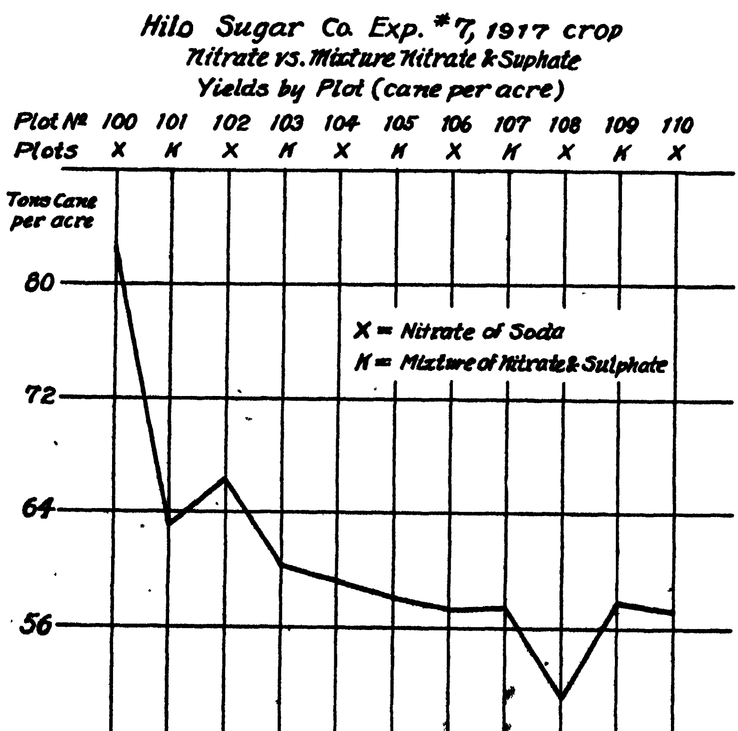
which an accurate sample can be secured by an automatic sampler. Stick samples at the best are not reliable. Despite attempts to pick stalks that form an average lot of cane from different parts of a plot, a true and very accurate test of the juice is impossible. What is obtained is only an indication of the sugar content.

RECORDING PROGRESS OF EXPERIMENT: Careful notes must be taken during the growing period of the cane on an experiment. There are many factors that may influence the growth of the cane, and unless record is made regularly during the two years it takes the crop to come to maturity, erroneous conclusions are likely to be drawn. These factors may be excessive rainfall, lack of water, uncontrolled weed growth, infestation of leaf-hopper, and the restraint they have on the welfare of the cane may be the limiting factor, obscuring completely the original plan of experiment. It is therefore essential that observations be made frequently, and notes put in permanent form for future reference.

Photographs are of special service in showing conditions of growth. Notes should be made of distance of camera from the object, height of camera, and if possible have some known comparison alongside the cane.

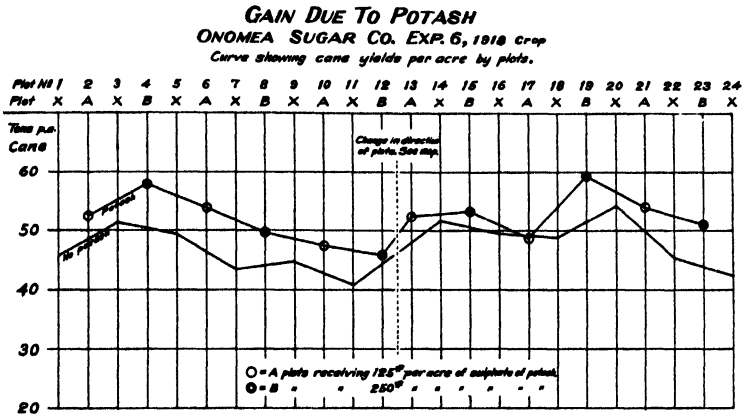
INTERPRETATION OF RESULTS.

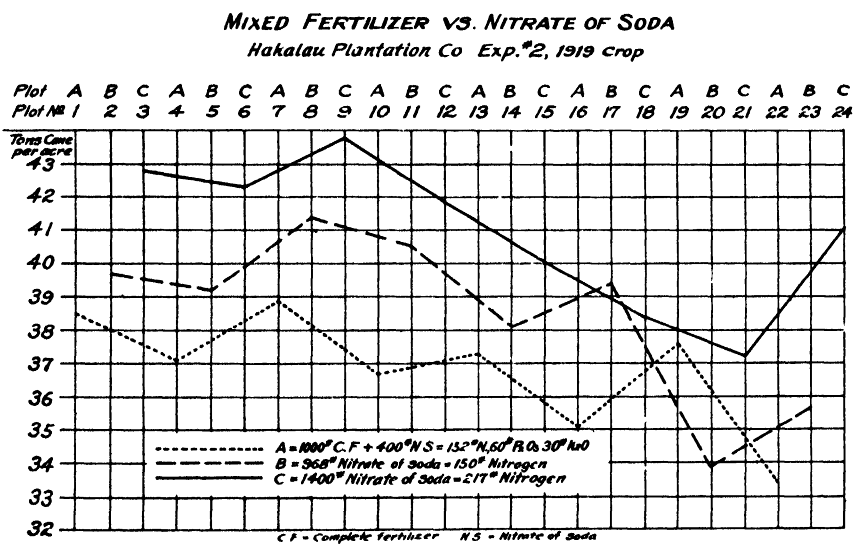
AVERAGING PLOT YIELDS: Usually by averaging the yields of the plots there can be tabulated figures showing the gain or loss due specific treatments.



Plot curve of Hilo Sugar Co. Experiment 7 (1917 Crop), which shows the average results to be unreliable. By leaving out plot No. 100, the results are entirely reversed. The results, therefore, had to be discarded as unreliable.

STUDY OF PLOT CURVE: No results should be interpreted without a study of the individual yields of each plot. The yields may be plotted on graph paper, and, when connected, form a curve that is very helpful in pointing out consistency of the results and to locate discrepancies or possible error. The following charts are examples of the use of plot curves:





These charts illustrate how consistent and accurate the results are which were obtained in these two experiments. In the above there is no doubt a decided gain for potash. In the other we are sure that nitrate of soda gave better yields throughout than mixed fertilizer.

Very erroneous results can be obtained if the distinct plot yields are disregarded, as a very high yield in one plot might distort the average yields upon which conclusions are based. An illustration is shown in Hilo Sugar Company Experiment 7 (1917 Crop) of how unreliable averages may be. The average results show a gain for the X plots of 3.84 tons cane over the K plots. When we study the plot curve it is seen that the higher yield for the X plots is largely due to the high yield of one individual plot (No. 100). By omitting this plot and substituting X plot at the oher end, the yield becomes 1.16 tons cane in favor of the K plots.

CONSIDERATION OF EXPERIMENTAL ERROR: At Waipio an experiment was laid out to study the unavoidable error in field testing. The entire area was divided into 1/40-acre plots. There was a difference in yield of 28% from two adjoining plots that were treated identically. In an experiment at Hilo Sugar Company there was a difference in yield of 24% between two similar plots separated by 30 feet.

Laying out and conducting an experiment is a long fight against this experimental error. When drawing conclusions from the data obtained from experiments the probability of experimental error must be considered. In the following table an analysis is made of experimental error and means of combatting it:

THE UNAVOIDABLE ERROR.	MEASURES TO COUNTERACT ERROR.
Varying conditions from plot to plot of— (1) Soil fertility: (a) Chemically, (b) Physically, (c) Biologically. (2) Moisture and rainfall. (3) Wind. (4) Irregularity in stand and growth.	1. Securing uniform topography. 2. Regulating the size of the plot to conform to conditions. 3. Arranging many repetitions of plots of like treatment. 4. Continuing the experiment for many seasons.
CONTROLLABLE ERROR.	**MEASURES TO CONTROL ERROR.**
1. Influence of one plot over adjacent plot. 2. Unevenness in: (a) preparation of field, (b) selection of seed, (c) application of fertilizer, (d) irrigation, (e) application of specific treatment. 3. Errors in harvesting cane. 4. Errors in sampling juices.	1. Guard rows. 2. Employing skilled and experienced workmen. 3. Careful supervision. 4. Well-located plots — straight and even lines. 5. Continuous sample of crusher juice from several consecutive carload lots.

CONTINUATION OF EXPERIMENT FOR MANY SEASONS: It is very important that experiments be continued from year to year. Results that are substantiated by the yields of several crops can be trusted and relied upon.

Perhaps one crop experienced excessive rainfall, or dry weather was a limiting factor. To illustrate how results are influenced by changes in growing conditions:

In Onomea Experiment No. 5 (1917 Crop) 132 lbs. of nitrogen gave a gain of 4.59 tons cane over 44 lbs. of nitrogen. For the 1919 crop the gain was only

2.05 tons cane. In the year 1916 the total rainfall was 231.19 inches; in the year 1918 the total precipitation was 304.14 inches.

Wailuku Experiment No. 1 (1917 Crop) gave a profitable gain up to 193 lbs. of nitrogen. In 1919 the addition of any nitrogen over 154 lbs. produced no increased yields. 1919 crop had to contend with a dry period when water was not abundant.

It is therefore very necessary that data be substantiated by years of the identical results due to a specific treatment. The famous Rothamsted experiments have been carried on without change for 40 years. Agricultural science has benefited greatly.

Mr. C. F. Eckart has said*: "The question of time needs be one of the most important points to be considered in forming an opinion as to the value of results. It is true that a one-crop experiment may occasionally allow one to safely draw deductions, but such instances are rare. * * * The smaller the difference in the production becomes, as manifested by the respective experiment areas, the less sure we are apt to feel that that difference was due to our changed treatment, and the less certain we should feel that this same difference would be maintained during a succeeding crop period. It becomes important, then, to repeat the experiments, not only once, but two or three times, in order to feel fully justified in condemning one practice and extolling another."

* H. S. P. A. Bulletin No. 13, 1905.

NOTE:—Charts have previously been published in the Record.

Annual Synopsis of Mill Data, 1919.

By W. R. McAllep.

This season the Synopsis contains reports from forty-one factories. This includes all of the factories, except one, in the Association. The factories sending in data produced 98.5% of the 1919 Hawaiian crop, the largest proportion that has so far been covered by the tabulations in the Annual Synopsis.

Last year the form of the large table was changed. The columns were rearranged, and the factories were listed in the order of the amount of sugar produced, based on the average for the preceding five seasons. This plan has been followed in compiling the tables this year.

Varieties of Cane Ground.

The principal varieties of cane ground by the different factories are listed in Table No. 1. The percentage for each variety of the total crop is also shown. The 1918 averages are included for comparison. A noticeable feature of this tabulation is the large decrease in the percentage of Lahaina. All of the other columns with the exception of the one for D-1135 show an increase. H-109 shows the largest increase of any of the minor varieties. This variety is now closely pressing D-1135 for third place.

Seventy-five per cent of the tonnage included in the column "Other Varieties" is made up of the following: Striped Mexican, Louisiana Striped, H-20, H-146, Yellow Bamboo, White Bamboo, H-227, H-333, and H-16. The above are listed in the order of the tonnage ground. Each was cultivated on some plantation to the extent of one per cent or more of the crop.

Composition of Cane by Islands.

The composition of the cane by islands is shown in Table 2. Without exception, the quality is better than it was in 1918. The polarization of the cane is higher in all cases. The purity of the first mill juice is also higher, with the single exception of the Island of Kauai.

For the whole group, the quality is much better than in 1918, slightly better than in 1916, but poorer than in other years since the synopsis has been published. Improved milling and boiling house work, together with the production of a sugar of lower polarization, have made up for the difference in quality with the result that less cane was required to make a ton of sugar than in any year since 1909.

Milling.

The average extraction has increased slightly. The "milling loss," or parts sugar per hundred parts of fiber in the bagasse, is, however, a better index of the efficiency of the mill work. The loss has increased slightly.

TABLE NO. 1.

VARIETIES OF CANE.

	Lahaina	Yellow Caledonia	D 1135	Striped Tip & Yellow Tip	Rose Bamboo	D 117	H 109	Other Varieties
H. C. & S Co.	81	..	7	..	..	..	11	1
Oahu	60	6	16	..	..	..	10	8
Maui Agr.	69	1	14	..	5	..	9	2
Ewa	25	13	1	..	..	..	53	8
Pioneer	83	1	1	..	..	..	..	15
Waialua	38	16	12	..	15	2	5	12
Haw. Sug.	59	..	24	..	..	..	8	9
Olaa	..	90	10	..	..	..	..	..
Honolulu	41	53	4	..	..	..	2	..
Onomea	..	99	..	1	..	..	..	..
Kekaha	92	..	6	..	..	..	..	2
Hakalau	..	100	..	..	..	..	..	..
Hilo	..	98	1	1	..	..	..	..
McBryde	7	37	35	..	..	..	21	..
Wailuku	53	1	7	..	..	..	4	35 *
Haw. Agr.	..	74	4	..	5	..	..	17
Lihue	..	100	..	..	..	..	..	..
Waiakea	..	100	..	..	..	..	..	..
Honokaa	..	49	15	34	..	..	2	..
Laupahoehoe	..	67	3	15	..	15	..	..
Makee	1	98	..	..	..	..	..	1
Lihue, Han	..	100	..	..	..	..	..	..
Kahuku	20	74	..	..	..	..	6	..
Pepeekeo	..	96	4	..	..	..	..	..
Paauhau	..	62	17	15	..	6	..	..
Koloa	10	89	..	..	..	..	..	1
Honomu	..	99	..	..	..	1	..	..
Hawi	..	54	8	37	..	..	..	1
Hamakua	..	57	7	7	..	25	1	3
Hutchinson	..	24	1	1	74	..	..	..
Kaeleku	..	100	..	..	..	..	..	..
Kaiwiki	..	61	1	2	17	19	..	..
Kilauea	..	95	5	..	..	..	..	..
Kohala	..	49	14	37	..	..	..	..
Waianae	95	1	..	..	..	..	3	1
Waimanalo	..	100	..	..	..	..	..	..
Niulii	..	100	..	..	..	..	..	..
Halawa	..	52	4	44	..	..	..	..
Olowalu	98	..	..	..	..	..	2	..
Waimea	91	..	..	..	..	..	9	..
Kipahulu	..	100	..	..	..	..	..	..
True Average 1919	29.1	46.4	7.2	2.9	2.1	1.1	6.8	4.4
" " 1918	37.9	42.9	7.5	2.0	1.1	0.8	4.0	3.8

* Striped Mexican 34.

TABLE NO. 2.

COMPOSITION OF CANE BY ISLANDS

	Hawaii	Maui	Oahu	Kauai	Whole Group
1910					
Polarization	13.53	15.90	14.54	14.00	14.47
Percent Fiber	12.91	11.19	12.75	13.12	12.39
Purity 1st Mill Juice....	88.52	91.60	88.12	88.25	88.90
1911					
Polarization	12.91	15.45	14.45	13.51	13.99
Percent Fiber	13.27	11.79	12.92	13.26	12.85
Purity 1st Mill Juice....	88.15	91.57	88.20	87.46	88.83
1912					
Polarization	13.30	16.00	14.38	14.06	14.34
Percent Fiber	13.53	11.53	12.62	12.59	12.67
Purity 1st Mill Juice....	88.40	91.13	88.46	88.30	89.04
1913					
Polarization	13.22	15.56	14.21	13.70	14.05
Percent Fiber	13.74	11.73	12.75	12.50	12.85
Purity 1st Mill Juice....	88.47	91.11	88.20	88.12	89.02
1914					
Polarization	12.75	15.16	14.23	13.62	13.78
Percent Fiber	13.62	11.59	12.44	12.75	12.74
Purity 1st Mill Juice....	88.22	91.02	88.11	87.51	88.71
1915					
Polarization	12.61	15.23	14.29	14.09	13.77
Percent Fiber	13.00	11.44	12.77	12.46	12.51
Purity 1st Mill Juice....	87.86	90.48	87.27	86.99	88.24
1916					
Polarization	12.54	14.62	13.74	13.26	13.45
Percent Fiber	13.22	12.22	12.51	12.86	12.74
Purity 1st Mill Juice....	87.56	89.41	87.15	86.26	87.70
1917					
Polarization	13.31	15.43	13.55	13.13	13.76
Percent Fiber	13.23	11.67	12.25	12.89	12.62
Purity 1st Mill Juice....	88.11	90.69	86.86	86.70	88.02
1918					
Polarization	11.88	14.25	13.50	12.54	12.97
Percent Fiber	13.35	11.53	12.23	12.84	12.50
Purity 1st Mill Juice....	87.27	88.62	86.93	85.88	87.18
1919					
Polarization	12.74	15.12	14.24	13.52	13.74
Percent Fiber	13.07	11.74	12.14	12.61	12.49
Purity 1st Mill Juice....	87.54	88.81	87.00	85.82	87.34

The increased milling loss would lead to the conclusion that the work of the mills was hardly equal to that of last year, were it not for two factors, unavoidable in a report of this kind. First, the figures for the mill work this year represent 97.2% of the total crop against 95.1% last year. The increment has been from factories doing work considerably below the average. If data from these factories had been included in last year's calculations, the figures for milling loss for the two seasons would have been practically the same. Second, more reliable, though less favorable figures are now being reported from a few of the factories that were formerly under inadequate chemical control. Though the influence of these factors on the averages is not large, it is sufficient to justify the conclusion that there has been some improvement in the average milling work during the past year.

Table No. 3 shows the factories arranged according to milling loss. 60% of them report a lower figure than for last year.

The improvement at some of the factories ranking high in the list has been particularly noticeable. Maui Agricultural Company has again established a record for milling loss, extraction ratio and extraction, the latter averaging 99.05 for the season. Onomea also passed previous records in milling loss. A third factory, Hawaiian Commercial and Sugar Company, passed previous records in extraction, obtaining for the season an average of 98.99.

Pepeekeo established a new record in milling loss, extraction ratio, and extraction for an eleven roller mill, finishing the season with an average extraction of 97.96. This factory reported better than 98 extraction for eleven consecutive weeks. Honomu, similarly equipped, reported better than 98 extraction for ten consecutive weeks. The results obtained at these two factories indicate that a better quality of work than has generally been considered practicable, can be obtained with the shorter trains.

Olaa, Hawaiian Agricultural Company, Laupahoehoe and Waiakea have also materially improved their standing in Table No. 3. Ewa, McBryde, Hawaiian Sugar, Waialua, Pioneer and Makee have each dropped several points in their relative rank.

During the preceding two seasons there was a tendency to use slightly less maceration water. This year more maceration has been used, and the high point reached in 1918 has been passed.

The moisture content of the bagasse is lower this season than has previously been reported. The average is over one per cent better than last year. Eighty per cent of the factories report an improvement in this respect.

Clarification.

The increase in purity from mixed juice to syrup was less satisfactory than in previous years. The purity of the mixed juice was 0.3 higher than last year, but due to the smaller increase in purity, the syrup was 0.08 lower. The syrup purity was, in fact, the lowest in recent years. The smaller increase in purity has been general, only eleven factories reporting a larger increase than a year ago. It is possible that the clarification has received less attention during the past year than formerly on account of the greater amount of attention that has

TABLE NO. 3.—MILLING RESULTS.

Showing the Rank of the Factories on the Basis of Milling Loss.

Factory	Milling Loss	Extraction Ratio	Extraction	Equipment
1. Maui Agr......	1.28	0.08	99.05	K(2),21RM66
2. Onomea	1.39	0.11	98.58	2RC60,S54,12RM66
3. H. C. & S. Co...	1.53	0.09	98.99	K(4),2RC78(2),S72(2),12RM78(2)
4. Waimea	1.54	0.12	98.70	2RC48,12RM42
5. Hakalau	1.75	0.13	98.31	2RC54,12RM9-60,3-66
6. Hilo	1.88	0.14	98.03	K,2RC60,12RM66
7. Pepeekeo	2.06	0.16	97.96	2RC54,9RM60
8. Wailuku	2.13	0.15	97.95	K,2RC72,12RM78
9. Ewa	2.20	0.16	98.17	K(2),20RM78
10. Paauhau	2.34	0.19	97.43	2RC60,12RM66
11. Olaa	2.41	0.20	97.32	K,S72,12RM78
12. Honomu	2.65	0.20	97.61	2RC60,9RM60
13. Koloa	2.69	0.21	97.07	K,2RC60,12RM66
14. Kilauea	2.71	0.24	97.05	K,S,3RC60,9RM60
15. Waianae	2.74	0.19	97.42	K,12RM60
16. McBryde	2.75	0.21	97.40	K,S54,9RM84
17. Haw. Agr......	2.79	0.22	97.01	3RC60,12RM66
18. Laupahoehoe ..	2.82	0.21	97.22	K(2),11RM60
19. Kahuku	2.91	0.24	96.78	3RC60,S54,9RM72
20. Lihue	2.96	0.22	96.99	K,2RC72,12RM78
21. Honokaa	3.03	0.26	96.64	K(2),14RM2-60,12-66
22. Haw. Sug......	3.04	0.20	97.66	K,2RC72,S72,12RM78
23. Waialua	3.06	0.20	97.41	K(2),14RM78
24. Honolulu	3.09	0.22	97.28	K(2),S54,11RM78
25. Oahu	3.26	0.22	97.41	K(4),S72,14RM78,12RM78
26. Kekaha	3.28	0.23	97.19	2RC54,9RM60
27. Pioneer	3.38	0.22	97.45	K,2RC60,S54,12RM72
28. Hutchinson	3.76	0.29	96.01	2RC60,9RM60
29. Waiakea	3.81	0.29	96.13	K(2),S42,11RM60
30. Lihue, Han.....	4.05	0.31	95.77	K,2RC72,9RM78
31. Kaeleku	4.16	0.38	94.65	K(2),11RM2-54,9-60
32. Kohala	4.19	0.32	96.15	K(2),S42,11RM60
33. Kaiwiki	4.39	0.33	95.81	K(2),11RM60
34. Olowalu	5.05	0.37	95.14	K,3RC48,9RM48
35. Hawi	5.25	0.38	95.16	K(3),3RC48,12RM3-48,9-54,S42,9RM54
36. Hamakua	5.29	0.41	94.45	K,2RC60,9RM60
37. Makee	5.90	0.46	94.23	K(2),9RM72
38. Halawa	8.74	0.70	90.79	K,2RC60,6RM50
39. Kipahulu	10.73	0.79	88.85	K,5RM3-42,2-54

been given to boiling and the handling of low grades. The clarification has a large influence on the final yield of sugar, and this important department should not be neglected.

The amount of lime used per ton of cane has increased, the increase being approximately in proportion to the increase in soluble solids per ton of cane.

Filter Pressing.

The tendency toward lower polarization of the press cake continues this year. Compared with last year, a lower weight of cake per cent cane, and a smaller loss of sugar per cent polarization of cane have been reported.

Evaporation.

The brix of the syrup, though not as high as in 1916, was higher than during the 1917 and 1918 seasons. While the problems in connection with the production of better refining sugar were being solved, the brix of the syrup was lowered. This was undesirable from the standpoint of heat economy, and was in most cases unnecessary. Many factories producing sugar of good grain now evaporate their syrup to a high density. The present average, 62.42, leaves considerable room for improvement. It can be increased several degrees without interfering with the production of good refining sugar.

The amount of water per ton of cane, evaporated in the multiple effects was the largest so far reported.

Commercial Sugar.

The polarization of the commercial sugar has been reduced to approximately the point it was in 1915 and 1916, before the size of the grain was increased.

A greater proportion of the sugar than in previous seasons was above the standard for size of grain.

Final Molasses.

A year ago a very gratifying decrease in the gravity purity, amounting to 0.96, was obtained. This year the molasses was reduced to 37.95 gravity purity, a point 1.12 below last year's average. The improvement has been general, only nine factories reporting a higher gravity purity than a year ago.

The figure 37.95 is the average purity of the molasses resulting from 86% of the total crop.

In order to calculate the value of the improvement in the low grade work it is necessary to estimate the gravity purities of the syrup and sugar from the reported apparent purities. Data covering a number of years from the factories determining both sucrose and polarization indicate that on the average it is necessary to add 0.8 to the apparent purity of the syrup and 0.3 to the apparent purity of the sugar to convert them to gravity purities. These corrections, added to the apparent purities, give 86.5 and 97.6 as the gravity purity of the syrup

and sugar. Applying the s. j. m. formula, we obtain the figure 91.82 for the theoretical recovery of sucrose % sucrose in the syrup. If, however, the gravity purity of the molasses had been 39.07 as it was in 1918, instead of 37.95, the recovery would be reduced to 91.43. Assuming that the actual recovery would be in proportion to these figures, the improvement in handling the low grade products has resulted in a yield of over 2,500 tons of sugar above what would have been obtained had the work been of the same quality as that of 1918. This amount of sugar is worth on the plantations at $120 per ton, more than $300,000.

On the same basis the gain over 1917 amounts to approximately 5000 tons worth over $600,000.

The attention now being given to this part of the work will without doubt result in further improvement.

Java is the only other country from which comparative data are available. The latest figures are those for the 1918 crop. The average for all the factories was 36.9. The average for the factories using the defecation process, similar to that used in Hawaii, was 37.2.

Gravity Solids and Sucrose Balance.

An increased number of factories have reported their results on the more reliable basis of true sucrose, as well as on polarization. The gravity solids and sucrose balances of the factories so reporting appear in Table No 4. In calculating these balances when the per cent of suspended solids in the mixed juice has not been determined, it has been estimated at 0.25%.

Boiling House Recovery.

Notwithstanding the fact that the purity of the syrup was lower than in recent years, the polarization recovered per cent polarization of the mixed juice is higher than in any year during the last ten except 1915. The recovery per cent polarization of the cane is higher than in any year for which figures are available.

A comparison of the polarization obtained per cent polarization in the syrup, with the estimated available sucrose appears in Table No. 5.

This table is largely a check on the chemical control. The results in the last column are only approximately exact, for it is necessary to make certain assumptions, the details of which are given in the footnote under the table. Examination of the figures for several years indicates that when the gravity purity of the molasses has been reported, the variation due to these assumptions is probably not over plus or minus one per cent.

When the figure for recovery on available is 101 or over, there are probably errors in the chemical control. Figures below 99 may be due to errors in the control. In this case there is, however, strong probability of an unrecorded loss.

For the factories that report these data, the more reliable figures based on true sucrose and gravity solids are given in Table No. 6. Except for the possibility of solids not sugar being volatilized during the boiling process, there

TABLE NO. 4.

GRAVITY SOLIDS AND SUCROSE BALANCES.

Factory	GRAVITY SOLIDS PER 100 GRAVITY SOLIDS IN MIXED JUICE				SUCROSE PER 100 SUCROSE IN MIXED JUICE			
	Press Cake	Commercial Sugar	Final Molasses	Undetermined	Press Cake	Commercial Sugar	Final Molasses	Undetermined
H. C. & S. Co.	4.5	80.4	12.3	2.8	0.2	92.4	5.8	1.6
Oahu	3.3	80.7	12.6	3.4	0.2	93.0	5.4	1.4
Maui Agr.	3.7	80.1	15.8	0.4	0.3	91.7	7.2	0.8
Pioneer	2.8	79.9	14.1	3.2	0.1	92.2	6.3	1.4
Waialua	6.8	75.0	15.7	2.5	0.1	89.9	7.5	2.5
Haw. Sug.	2.8	77.8	16.8	2.6	0.3	90.2	7.9	1.6
Onomea	4.5	80.0	14.1	1.4	0.1	92.7	5.9	1.3
Hakalau	4.4	79.8	12.8	3.0	0.2	92.8	5.5	1.5
Hilo	4.5	78.9	13.9	2.7	0.2	92.5	5.9	1.4
Wailuku	3.7	78.2	16.2	1.9	0.3	91.9	7.2	0.6
Haw. Agr.	4.1	79.5	15.7	0.7	0.1	91.2	7.2	1.5
Honokaa	5.3	71.6	22.9	0.2	0.2	88.2	10.7	0.9
Pepeekeo	5.0	78.0	13.2	3.8	0.1	92.0	5.5	2.4
Paauhau	5.1	77.0	17.3	0.6	0.3	91.5	7.8	0.4
Honomu	5.0	79.2	14.0	1.8	0.3	92.6	5.8	1.3
Hutchinson	3.2	78.6	13.3	4.9	0.1	90.9	6.4	2.6
Kilauea	3.7	67.9	24.1	4.3	0.3	84.3	12.4	3.0
Kohala	5.3	77.4	13.5	3.8	0.2	92.6	6.3	0.9

TABLE NO. 5.

APPARENT BOILING HOUSE RECOVERY.

Comparing percent. available sucrose in the syrup (calculated by formula) with percent. polarization actually obtained.

Factory	Available *	Obtained	Recovery on Available
H. C. & S. Co	93.06	93.34	100.3
Oahu	93.00	94.05	101.1
Maui Agr	93.03	91.96 †	98.8
Ewa	91.68	92.06	100.4
Pioneer	92.37	92.24	99.9
Waialua	92.12	90.33	98.1
Haw. Sug	91.03	91.09	100.1
Olaa	92.11	90.50	98.3
Onomea	93.75	93.12	99.3
Kekaha	91.55	90.95	99.3
Hakalau	93.12	93.04	99.9
Hilo	93.65	92.63	98.9
McBryde	89.75	88.67	98.8
Wailuku	91.71	92.67	101.0
Haw Agr	93.16	91.67	98.4
Lihue	89.72	89.08	99.3
Waiakea	90.19	88.08	97.7
Honokaa	90.06	88.30	98.0
Laupahoehoe	93.11	94.02	101.0
Makee	88.31	87.59	99.2
Lihue, Han	90.84	89.14	98.1
Kahuku	88.54	87.43	98.7
Pepeekeo	93.41	92.28	98.8
Paauhau	91.83	92.16	100.4
Koloa	87.83	87.08	99.1
Honomu	93.70	93.17	99.4
Hawi	92.38	87.93	95.2
Hamakua	89.77	91.07	101.4
Hutchinson	91.26	91.47	100.2
Kaeleku	85.04	87.94	103.4
Kaiwiki	91.71	93.07	101.5
Kilauea	85.72	85.42	99.7
Kohala	91.62	93.50	102.1
Waianae	88.71	87.03	98.1
Halawa	92.54	85.05	91.9
Olowalu	87.36	84.25	96.4
Waimea	91.66	88.81	96.9
Kipahulu	91.49	85.55	93.5

* In order to calculate the available sucrose it is necessary to estimate the gravity purity of the syrup and sugar. Data from factories determining both apparent and gravity purities indicate that the average correction necessary is the addition of 0.8 to the apparent purity of the syrup and 0.3 to the apparent purity of the sugar. When the moisture in the sugar has not been reported 1% has been taken. 38 has been used when the gravity purity of the molasses has not been reported.

† Sucrose.

TABLE NO. 6.

TRUE BOILING HOUSE RECOVERY.

Comparing percent. sucrose available and recovered.

Factory	Available	Obtained	% Recovery on Available
H. C. & S. Co................	93.06	92.59	99.5
Oahu........................	93.11	93.19	100.1
Maui Agr................	93.03	91.98	98.9
Pioneer.....................	92.30	92.29	100.0
Waialua.....................	92.27	89.99	97.5
Haw. Sug...................	91.11	90.47	99.3
Onomea.....................	93.96	92.79	98.8
Hakalau....................	93.31	92.99	99.7
Hilo........................	93.21	92.69	99.4
Wailuku....................	91.85	92.18	100.4
Haw. Agr...................	93.21	91.29	97.9
Honokaa.................. ..	89.62	88.38	98.6
Pepeekeo...................	93.39	92.09	98.6
Paauhau................	92.05	91.78	99.7
Honomu.............	93.68	92.88	99.1
Hutchinson..............	91.41	90.99	99.5
Kilauea...............	85.90	84.55	98.4
Kohala.....................	91.42	92.79	101.5

would appear to be no reason why the reported per cent sucrose recovered on available should exceed 100.

On account of the attention now being given to the low grade work it is of interest to compare the quantity of molasses produced with the theoretical amount. For the factories reporting sucrose and gravity solids this comparison is given in Table No. 7. Two values may be used for the theoretical amount of molasses. Both are given in the table. The first column is the commonly used figure. This is based on the assumption that the solids in the syrup, less those recovered in the sugar should appear in the molasses. The figures in the second column are based on somewhat different reasoning. The recovery indicated by the s. j. m formula is subtracted from the sucrose and solids in the syrup and the remainder taken as the theoretical amount of molasses.

Two-thirds of the factories listed in Table 7 failed to account for as much as 90% of the theoretical amount of molasses. Without more definite information it is hard to account for the discrepancy. It is true that the solids in the molasses are a small proportion of the total entering the boiling house and that an error in the brix would make a considerable difference in the calculated amount of molasses. With hydrometers of the precision of those now available, there should hardly be a constant error of over 0.1 degree in the brix. A calculation shows that this error would amount to about 5% of the calculated amount of molasses, much less than the discrepancy shown by many of the factories. Undoubtedly

TABLE NO. 7.

PERCENT. MOLASSES PRODUCED ON THEORETICAL.

	Assuming Theoretical Solids in Molasses as Solids in Syrup Less Solids Recovered in Sugar	Assuming Theoretical Solids in Molasses as Solids in Syrup Less Solids in "Available" Sugar
H. C. & S. Co.	81.7	84.1
Oahu	78.8	78.8
Maui Agr.	97.3	102.9
Pioneer	81.5	82.3
Waialua	86.5	97.0
Haw. Sug.	86.3	88.8
Onomea	91.3	98.2
Hakalau	81.0	82.5
Hilo	84.0	86.0
Wailuku	89.7	88.3
Haw. Agr.	95.6	106.9
Honokaa	99.0	103.4
Pepeekeo	77.4	82.9
Paauhau	96.7	98.0
Honomu	88.6	92.4
Hutchinson	73.1	74.7
Kilauea	84.9	88.4
Kohala	78.0	78.4

also, some volatilization of solids takes place, though to what extent this occurs we have little information.

Factory Efficiency.

The standing of the factories according to efficiency is shown in Table No. 8. The arbitrary standard used for comparison may be expressed as a factory grinding the same cane, obtaining the same increase in purity from mixed juice to syrup, and producing sugar of the same analysis, but obtaining 100% extraction, reducing the final molasses to 30 gravity purity, and having no losses other than molasses. This standard is the same as that used a year ago.

Factories reporting a recovery of 101% or more on available (Table No. 5) have been omitted from this tabulation.

Losses In Manufacture.

The loss in molasses, the largest of these losses, is now somewhat larger than it was half a dozen years ago when figures comparable with the present were first compiled. This is not due to poorer work, but to lower juice purities. Had it not been for improvements in the boiling house work this loss would now be considerably larger than the present figures. The attention now being given to the low grade work will reduce this figure provided the juices do not

TABLE NO. 8.

FACTORY EFFICIENCY.

Showing the comparative standing of the plantations on the basis of the entire factory work.

No.	Factory	Total Recovery		Factory Efficiency
		Calculated	Obtained	
1	Onomea	94.85	91.73	96.71
2	Ewa	93.26	90.15	96.67
3	H. C. & S. Co	95.47	92.25	96.63
4	Hakalau	94.60	91.28	96.49
5	Honomu	94.73	90.68	95.72
6	Pepeekeo	94.48	90.28	95.55
7	Hilo	94.84	90.61	95.54
8	Maui Agr	95.16	90.84 †	95.46
9	Paauhau	93.83	89.46	95.34
10	Pioneer	94.30	89.77	95.20
11	Haw. Sug	93.98	88.63	94.31
12	Kekaha	94.28	88.03	93.37
13	Haw. Agr	95.36	88.87	93.19
14	Lihue	92.41	86.10	93.17
15	Hutchinson	94.18	87.74	93.16
16	Kahuku	90.80	84.46	93.02
17	Waimea	94.10	87.50	92.99
18	Waialua	94.53	87.88	92.97
19	Olaa	94.48	87.80	92.93
20	McBryde	92.97	86.27	92.79
21	Koloa	91.44	84.31	92.20
22	Honokaa	92.46	85.16	92.10
23	Lihue, Han	92.85	85.09	91.64
24	Kilauea	90.78	82.69	91.09
25	Waianae	92.63	84.37	91.08
26	Waiakea	94.00	84.49	89.88
27	Makee	91.93	82.22	89.44
28	Hawi	94.41	83.30	88.23
29	Olowalu	92.29	79.94	86.62
30	Halawa	94.55	77.15	81.60
31	Kipahulu	93.75	75.14	80.15

† Sucrose.

show further decrease in purity. An opportunity to reduce this loss lies in obtaining a greater increase in purity from mixed juice to syrup.

Second in size is the loss in bagasse. This has been reduced from a point as high if not higher than the loss in molasses till it is now less than 40% of the latter figure. There is still room for improvement, since many of the factories are far behind the leaders in this respect.

The smallest of the determined losses is that in press cake. The amount of press cake handled has increased from year to year on account of the more efficient mill work and better settling equiomnent. The polarization has been

reduced but on account of the increased quantity of cake handled, the loss has not changed greatly in recent years.

During the past ten years the total losses have been reduced from 15.54 to 11.43. The real improvement has been greater than the difference between these figures would indicate. The losses have been reduced notwithstanding a steady decrease in the purity of the juice of the cane, which would tend to increase them. Also, the figure 15.54 represents the losses of some two-thirds of the factories only, the others not being under sufficiently complete chemical control at that time to report such data.

The undetermined loss has also usually been reduced from year to year. This year, however, the undetermined is somewhat higher—1.27, which is some 45% of the loss in bagasse. There is of course some question as to what extent this loss is real and to what extent it is due to discrepancies in the control. With the high quality of work now being done this figure is of sufficient magnitude to receive careful investigation to the end that any real losses that are included in it may be found and if possible stopped.

A summary of the losses is given in Table No. 9.

The calculations and tables in this synopsis have been made almost entirely by Mr. Brodie.

TABLE NO. 9.

SUMMARY OF LOSSES.

FACTORY	POUNDS POLARIZATION PER TON OF CANE						POLARIZATION PER 100 CANE						POLARIZATION PER 100 POLARIZATION OF CANE						Syrup Purity	FACTORY
	Bagasse	Press Cake	Molasses	Other Known	Undetermined	TOTAL	Bagasse	Press Cake	Molasses	Other Known	Undetermined	TOTAL	Bagasse	Press Cake	Molasses	Other Known	Undetermined	TOTAL		
H. C. & S. Co.	3.2	0.4	18.8	...	2.4	24.8	0.16	0.02	0.94	...	0.12	1.24	1.01	0.15	5.84	...	0.74	7.74	87.98	H. C. & S.
Oahu	7.6	0.6	15.6	...	1.2	25.0*	0.38	0.03	0.78	...	0.06	1.25*	2.59	0.20	5.35	...	0.43	8.57*	86.5	Oahu.
Maui Agr.	3.0	0.8	22.2	...	2.6	28.6†	0.15	0.04	1.11	...	0.13	1.43†	0.95	0.27	7.08	...	0.86	9.16†	88.09	Maui Agr.
Ewa	5.2	0.8	20.6	...	1.2	27.8	0.26	0.04	1.03	...	0.06	1.39	1.83	0.26	7.34	...	0.43	9.96	84.28	Ewa.
Pioneer	7.6	0.4	18.6	0.4	3.8	30.8	0.38	0.02	0.93	0.02	0.19	1.54	2.55	0.13	6.19	0.16	1.21	10.24	85.85	Pioneer.
Waialua	7.6	0.4	22.0	...	6.2	36.2	0.38	0.02	1.10	...	0.31	1.81	2.59	0.13	7.34	...	2.07	12.13	86.7	Waialua.
Haw. Sug.	7.0	1.0	23.4	...	2.8	34.2	0.35	0.05	1.17	...	0.14	1.71	2.34	0.36	7.74	...	0.93	11.37	85.56	Haw. Sug.
Olaa	6.4	0.8	21.6	...	0.8	29.6	0.32	0.04	1.08	...	0.04	1.48	2.68	0.30	8.93	...	0.29	12.20	86.5	Olaa.
Honolulu	7.8	0.4	24.8	...	...	...	0.39	0.02	1.24	...	...	...	2.72	0.14	8 75	...	....	....	87.22	Honolulu.
Onomea	3.6	0.2	14.6	...	2.2	20.6	0.18	0.01	0.73	...	0.11	1.03	1.42	0.07	5.89	...	0.89	8.27	86.9	Onomea.
Kekaha	8.0	1.2	23.2	...	2.0	34.4	0.40	0.06	1.16	...	0.10	1.72	2.81	0.40	8.06	...	0.70	11.97	85.95	Kekaha.
Hakalau	4.6	0.6	14.6	...	3.6	23.4	0.23	0.03	0.73	...	0.18	1.17	1.69	0.21	5.44	...	1.39	8.73	86.1	Hakalau.
Hilo	5.2	0.6	15.0	...	3.8	24.6	0.26	0.03	0.75	...	0.19	1.23	1.97	0.22	5.72	...	1.48	9.39	87.04	Hilo.
McBryde	7.0	0.2	28.2	...	1.2	36.6	0.35	0.01	1.41	...	0.06	1.83	2.60	0.11	10.55	...	0.47	13 73	83.96	McBryde.
Wailuku	5.8	0.8	20.0	...	0.2	26.8*	0.29	0.04	1.00	...	0.01	1.34*	2.05	0.27	7.10	...	0.07	9.49*	84.8	Wailuku.
Haw. Agr.	7.4	0.2	18.0	...	2.4	28.0	0.37	0.01	0.90	...	0.12	1.40	2.99	0.07	7.09	...	0.98	11.13	87.68	Haw. Agr.
Lihue	8.0	0.8	...	...	28.0	36.8	0.40	0.04	...	...	1.40	1.84	3.01	0.33	....	...	10.56	13.90	82.9	Lihue.
Waiakea	10.0	0.6	...	...	29.6	40.2	0.50	0.03	...	...	1.48	2.01	3.87	0.20	....	...	11.44	15.51	85.54	Waiakea.
Honokaa	7.8	0.4	24.0	...	2.0	34.2	0.39	0.02	1.20	...	0.10	1.71	3.36	0.19	10.38	...	0.91	14.84	83.11	Honokaa.
Laupahoehoe	7.4	0.4	14.6	...	0.6	23.0*	0.37	0.02	0.73	...	0.03	1.15*	2.78	0.15	5.57	...	0.23	8.73*	87.89	Laupahoehoe.
Makee	14.6	1.0	26.8	...	2.8	45.2	0.73	0.05	1.34	...	0.14	2.26	5.77	0.37	10.56	...	1.09	17.79	82.50	Makee.
Lihue-Han.	10.6	0.8	...	...	26.2	37.6	0.53	0.04	...	...	1.31	1.88	4.23	0.31	....	...	10.37	14.91	83.6	Lihue-Han.
Kahuku	7.6	0.4	26.2	...	2.8	37.0	0.38	0.02	1.31	...	0.14	1.85	3.22	0.17	10.95	...	1.19	15.53	80.68	Kahuku.
Pepeekeo	5.2	0.4	14.0	...	5.6	25.2	0.26	0.02	0.70	...	0.28	1.26	2.04	0.12	5.41	...	2.15	9.72	86.05	Pepeekeo.
Paauhau	6.4	0.8	19.0	...	0.0	26.2	0.32	0.04	0.95	...	0.00	1.31	2.57	0.35	7.61	...	0.00	10.53	85.15	Paauhau.
Koloa	7.6	0.6	27.8	...	4.8	40.8	0.38	0.03	1.39	...	0.24	2.04	2.93	0.25	10.69	...	1.82	15.69	81.4	Koloa.
Honomu	6.4	0.8	15.4	...	2.4	25.0	0.32	0.04	0.77	...	0.12	1.25	2.39	0.28	5.72	...	0.93	9.32	86.7	Honomu.
Hawi	13.4	1.2	...	...	31.6	46.2	0.67	0.06	...	...	1.58	2.31	4.84	0.42	....	...	11.43	16.69	86.09	Hawi.
Hamakua	14.2	0.2	11.6	...	10.0	36.0*	0.71	0.01	0.58	...	0.50	1.80*	5.55	0.09	4.54	...	3.88	14 06*	84.5	Hamakua.
Hutchinson	10.2	0.2	16.0	...	5.0	31.4	0.51	0.01	0.80	...	0.25	1.57	3.99	0.09	6.21	...	1.97	12.26	86 2	Hutchinson.
Kaeleku	11.8	1.2	...	...	24.8	37.8*	0.59	0.06	...	...	1.24	1.89*	5.35	0.54	....	...	11.35	17.24*	81.82	Kaeleku.
Kaiwiki	11.2	0.6	...	...	17.8	29.6*	0.56	0.03	...	...	0.89	1.48*	4.19	0.24	....	...	6.62	11.05*	85.65	Kaiwiki.
Kilauea	6.6	0.6	27.4	...	4.2	38.8	0.33	0.03	1.37	...	0.21	1.94	2.95	0.25	12.24	...	1.87	17.31	80.7	Kilauea.
Kohala	10.0	0.6	16.0	...	0.4	27.0*	0.50	0.03	0.80	...	0.02	1.35*	3.95	0.20	6.13	...	0.11	10.29*	85.6	Kohala.
Waianae	7.4	1.4	...	...	36.2	45.0	0.37	0.07	...	...	1.81	2.25	2.58	0.47	....	...	12.58	15.63	83.36	Waianae.
Waimanalo	...	1.6	...	...	...	...	...	0.08	...	...	...	...	....	...	....	...	....	....	.....	Waimanalo.
Niulii	24.0	1.2	...	...	...	...	1.20	0.06	...	...	...	...	....	...	....	...	....	....	87 5	Niulii.
Halawa	23.0	0.2	...	...	34.0	57.2	1.15	0 01	...	...	1.70	2.86	9.21	0.07	....	...	13.56	22.84	85.93	Halawa.
Olowalu	13.4	0.8	14.8	...	26.6	55.6	0.67	0.04	0.74	...	1.33	2.78	4.86	0.25	5.33	...	9.62	20.06	82.59	Olowalu.
Waimea	3.4	0.4	...	...	28.4	32.2	0.17	0.02	...	...	1.42	1.61	1.30	0.18	....	...	11.02	12.50	85.57	Waimea.
Kipahulu	30.2	2.8	...	...	34.4	67.4	1.51	0.14	...	...	1.72	3.37	11.15	1.02	....	...	12.69	24.86	85.88	Kipahulu.

* A comparison of the available sucrose in the juice with the amount recovered in the boiling-house indicates that there is probably an error in some of the results reported from this factory.

† Sucrose.

THE HAWAIIAN PLANTERS' RECORD

Volume XXII. FEBRUARY, 1920 Number 2

A monthly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

The Forest of Mt. Gedeh, West Java.

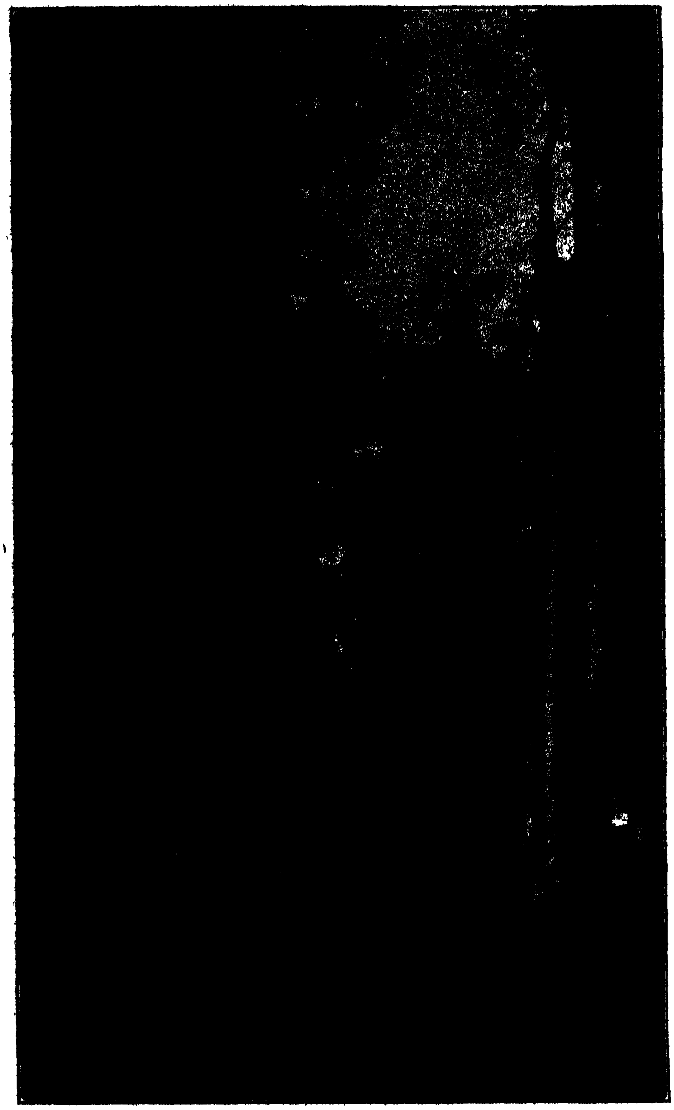
A Report on a Collecting Trip.

By Joseph F. Rock.*

The writer was duly commissioned by the Director of the Hawaiian Sugar Planters' Experiment Station to proceed to Java and Burmah for the purpose of collecting seeds, in quantity, of the most promising forest trees occurring on Mt. Gedeh, in West Java; he was also asked to go to Burmah for the purpose of obtaining quantities of seeds of *Taraktogenos Kurzii* King, the well-known Chaulmoogra tree, from the seed of which, Chaulmoogra oil, the only successful remedy in the treatment of leprosy, is derived.

In compliance with his commission, he left Honolulu on May 11th for Japan, where he was to obtain an amendment to his passport, which then read for Japan only. Owing to lack of steamship accommodations between Hongkong and Singapore, the writer was forced to proceed to Swatow and thence to Bangkok, Siam, the only possible way of reaching Singapore. At Bangkok he had his passport further amended, without difficulty, for Burmah and India. While in Siam he investigated the leprosy question and reported in full to Dr. A. L. Dean, President of the College of Hawaii. He is especially indebted to Dr. Mordern Carthew, of the Siamese Public Health Department, who had carried on investigations for several years in leprosy and who was treating leprosy cases in the main prison of Bangkok with Gynocardate of Sodium A, the active principle of Chaulmoogra separated by Dr. Leonard Rogers of Calcutta. Dr. Carthew's reports, both published and unpublished, the writer sent to Dr. Dean, with a quantity of the drug, such as is used by Dr. Rogers and Dr. Carthew. He also obtained seeds of *Hydnocarpus anthelminthicus*, a native of Siam, and there used in the cure of leprosy. It contains practically the same active principle as Chaulmoogra. Notwithstanding reports that the seeds of species of *Taraktogenos* and *Hydnocarpus*

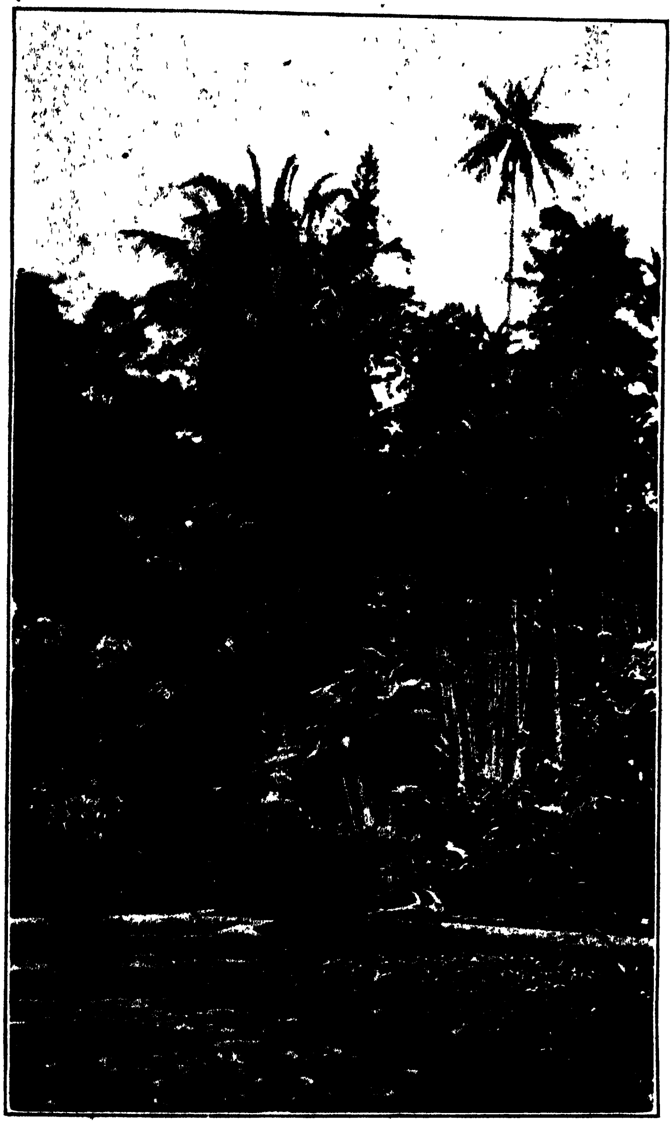
* Professor Systematic Botany, College of Hawaii.



Entrance to the Botanic Garden at Buitenzorg, Java.
Avenue of *Canarium commune*, or Java almond trees. Each tree is clothed with a species of Aroid, the roots of one of which can be seen on the left in the picture.

will not stand transportation, as they lose their germinating power rather quickly, the seeds sent have already germinated, though they were a month and a half in transit. Other seeds were secured in Siam, one of which is a species of fruit tree known in Siam as *Kathorn,* or scientifically as *Sandoricum indicum.* From Siam the writer proceeded to Singapore by boat, arriving there the first of August. After a short illness he proceeded via the Rhio Archipelago and the Island of Biliton to Batavia, Java. Immediately he took the train near the landing at Tandjong Priok for Buitenzorg, the seat of the government of Java, situated on the Volcano of Salak.

The authorities were exceedingly kind to him, and he renewed acquaintances from his last visit to Java in 1916. Work immediately began in the Botanic Gardens and seeds were collected through the kindness of Mr. Wigman, Curator



A group of palms in the gardens at Buitenzorg; the large palm in the center is *Schelea regia.*

of the Garden. The Director of the Garden was most hospitable and aided the writer in every way, so that his mission was successful. He is especially indebted to the Director of Agriculture, Mr. Sibinga Mulder, for privileges granted; to the Chief of Laboratories of the Treub Laboratory, and to Dr. H. S. Koorders for many valuable suggestions, kindness and hospitality.

Fitted out with permits, the writer proceeded to Tjanjor by train, where he took a motor to Tjipanas; coolies had previously been arranged for and were awaiting him at the Tjipanas post office. From there the ascent was begun to Tjibodas, where are situated the Treub Botanical Laboratory for visiting foreign and local biologists and the acclimatization gardens; this is at an elevation of 4500 feet. Tjibodas is situated on the slopes of the active Volcano of Gedeh, and immediately back of the laboratory commences one of the finest forest reserves in Java. It is in this reserve that the writer collected and caused to have collected

seeds of all the forest trees which were then in fruit; he not only collected seeds of trees, but also of shrubs and herbaceous plants, which, together, make up the plant associations on Mt. Gedeh. Including the seeds collected at the gardens at Buitenzorg, the writer had over three hundred and fifty species of trees and shrubs represented in the collection. A number suffered considerably on the voyage

The Treub Laboratory for visiting botanists at Tjibodas, Mt. Gedeh, Java. The large tree to the left, near house, is *Altingia excelsa*, the *Rasamala* tree of Java.

through the tropics and especially in the hold of the steamers in transit, so that the number of species of seeds introduced amounts to 287.

Owing to lack of time and also funds he was unable to proceed to Burmah, and after carefully packing the seeds in charcoal, etc., he proceeded to Singapore and thence to Japan, where he boarded the steamer Nippon Maru on October 4 for Honolulu. In order to give an idea of the forests of Gedeh and the work carried on there by the Dutch Government, the writer will give a more or less detailed account of the forest reserve on that mountain. He not only stayed at Tjibodas, whence he crossed the forests in every possible direction, but he also camped at the second rest-house, Kandang Badak, at an elevation of about 7500 feet. He ascended to the summit crater of Mt. Gedeh, nearly 10,000 feet in height, and collected seeds of the upland trees also. He took numerous photographs illustrating the various floral zones from sea level to 10,000 feet elevation. Owing to the enormous height of the trees, it was, of course, impossible to photograph individual trees, but smaller plants, groups of plants and trunks of the mighty monarchs of the forest were photographed, and a number of these are here reproduced. The photos were all taken by the writer. (The following is a floristic description of the plant covering on Mt. Gedeh.)

Before going into a detailed description of the forests of Gedeh, the writer wishes to give an account of the botanical gardens both at Buitenzorg and Tji-

bodas. Without exception, the gardens at Buitenzorg are the finest in the world; they were founded in 1814 at a time when the location was selected as the seat of the government owing to the cooler climate and much healthier surroundings than prevailed at Batavia. The entrance to the garden is formed by an avenue of *Canarium commune* or Java almond trees, which were planted by Theysmann, the well-known Dutch botanist. To the left is a pond with an island, on which are stately sealing-wax palms, *Cyrtostachys Rendah, Pandani,* etc., while floating in the water are huge *Victoria regia* and numerous other water lilies.

In the acclimatization garden at Tjibodas. In the foreground the renowned grass trees (*Xanthorrhoea*) belonging to the Lilyfamily, (natives of Australian savannahs); elevation 4500 feet.

There are at least ten thousand species of trees and shrubs represented, most of them native of Java and the neighboring islands such as Borneo, Celebes, Sumatra. Amboina, Timor, New Guinea, etc. The palm sections are especially wonderful, as they represent the finest collections of mature palms found in the world.

There are many wonderful Banyan or Ficus trees, *Sterculia* trees with scarlet flowers and the most striking leguminous flowering trees, such as *Amherstia nobilis* and various species of *Brownea* and *Saracca.* Space does not permit to go into detail here, and the few illustrations will have to suffice to give an idea of the marvelous beauty and grandeur of the gardens.

At Tjibodas are situated the acclimatization gardens at 4500 feet elevation. Trees can be found there which are restricted to cooler climes. Of especial interest are the Grass trees *Xanthorrhoea* of Australia, which are growing to perfection, besides huge tree ferns and many conifers.

Immediately back of the garden begins the actual virgin forest. The whole mountain has been set aside as a forest reserve and is known as a "Nature Monument," set aside for study and also for the utilitarian purpose of a watershed.

The forests of Java have been rapidly destroyed, as the area of the island is not too large for the support of about 34,000,000 people. Agriculture has encroached onto the slopes of mighty mountains and consequently the forests had to go. The Government took steps in time to prevent the complete destruction of forests by setting aside forest reserves or "Nature Monuments" in various parts of Java. The forests of Gedeh are by far the finest in the whole of Java. The forest is inhabited by many beautiful birds; also monkeys, barking deer, snakes, etc. These it is not permitted to hunt, and signs are posted near the approach to the actual forests giving notice of certain rules which must be obeyed while on the premises.

View of a portion of the acclimatization garden at Tjibodas, Mt. Gedeh.

At the edge of the forest, at 4500 feet elevation, the Government erected a botanical laboratory, and also living quarters for visiting biologists, by far the greater number of which are botanists. The charges for rooms are very nominal. Permits are issued by the Director of the Botanical Garden and the Chief of Laboratories.

Owing to the facilities extended, the forests of Gedeh have been studied extensively. Dr. Koorders has just published the results of his researches in a work entitled, "The Flora of Tjibodas."

He has studied these forests since 1890, at which time he selected a few specimens of each tree species occurring in the forest, labelled them and took growth measurements of their trunks since that time. Each tree bears a number and name, and under each number in separate publications and in the first part of his Flora of Tjibodas he has published the rate of growth both in height and diameter of trunk.

The Forest of Gedeh is composed of 165 species of trees, 350 species of

Castanea tungurut Bl. One of the species of chestnut at the entrance to Gedeh forest reserve; the tree is over 90 feet high and has a diameter of 50 inches.

shrubs and herbs, and 60 species of climbing plants; these make up the virgin forest, which has preserved its original character because man has left it almost or entirely undisturbed. Its trees remain standing until they die a natural death or succumb in the struggle with their neighbors, and thereafter their corpses sink into the ground, moulder away and leave a bare space where other species commence to battle.

In this as well as other tropical rain forests we find usually so many stories of plants that the whole nearly forms a single complex of vegetation, or, in other words, forest is piled upon forest. The trees forming the highest story on Mt. Gedeh are the Rasamala trees *Altingia excelsa*, reaching a height of 180 feet. At the higher levels their place is taken by a similarly tall tree, *Podocarpus imbricata*, a conifer of the family *Taxaceae*.

Tree ferns on Mt. Gedeh. *Alsophylla glauca* var. *densa*. These ferns are about 50 feet in height. They are very common in the forests about Tjibeurum, Mt. Gedeh.

Junghun, the famous naturalist and writer on Java, distinguished four zones on Gedeh which the writer will describe here briefly.

The early morning and up to ten o'clock is usually sunny, and also the peaks of both Gedeh and Pangerango are clear. Clouds begin to gather around the summit of the mountains rather early, and gradually descend to 5000 feet elevation. The sun shines usually at noon at Tjibodas, while a little later fog envelops the whole mountain and downpours begin at about two o'clock. At five in the evening the atmosphere clears again, and while it darkens again later in the evening, the summit can often be seen at sunset time. The nights and early mornings are, however, usually clear.

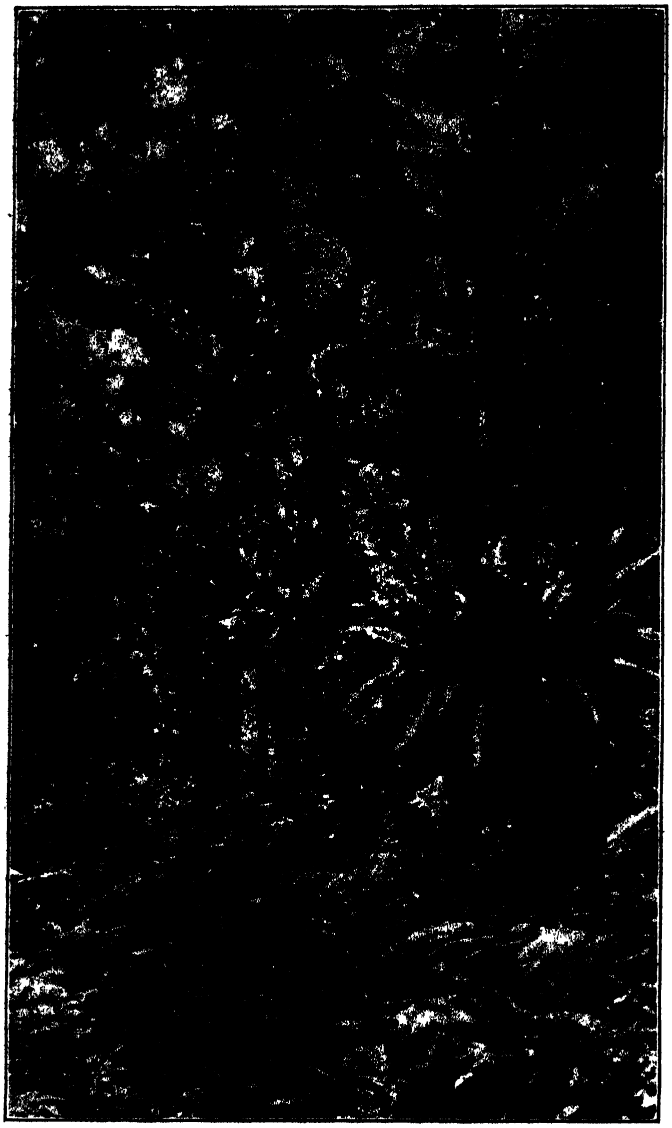
The first zone, or hot region, is from sea level to 2000 feet, and does not interest us here, as it does not contain forest trees of any extent, especially as

Trunk of *Altingia excelsa* Nor. The Rasamala is the tallest forest tree of Java, reaching a height of 180 feet. Ferns, mosses, liverworths and climbing aroids cover the trunk. In the second zone, elevation 4600 feet.
The views which follow are arranged in about the order they were photographed in ascending the mountain to its summit.

the forests of Gedeh commence actually with the second or temperate zone, from 2000 to 4600 feet and over. The cool region is from 4600 to 7600 feet, and the cold, including the alpine region, from 7600 to 10,000 feet.

The Temperate Region.

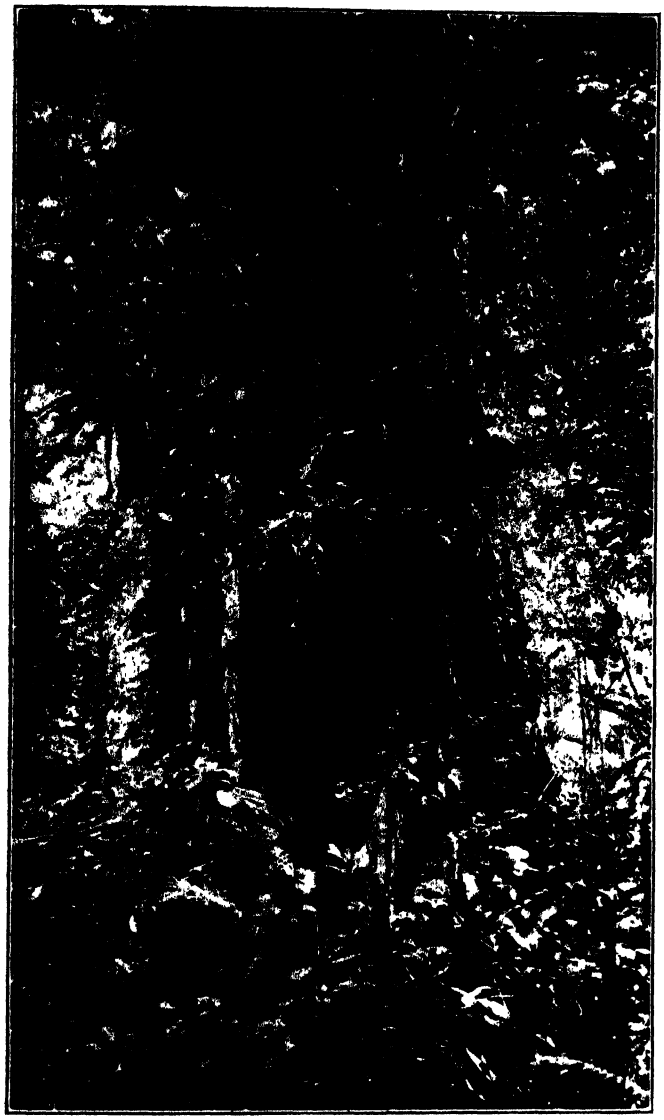
The forests of the second zone, which correspond in Hawaii to our 2000-foot level, are especially pronounced, owing to the various species of figs which here predominate. Mention may be made of the enormous species of *Ficus involucrata,* which reaches large dimensions, especially as to size of trunk (see plate). The tree reaches a height of over 100 feet or more and has a trunk diameter of nearly six feet. Other species and the next in size is *Ficus varie-*



Forest scene; the trees are mostly Poespa—*Schima Noronhae.* The undergrowth is composed mainly of Bubukuan—*Strobilanthus cernua*; the fern to the right on the trunk is *Asplenium nidus,* the bird's nest fern.

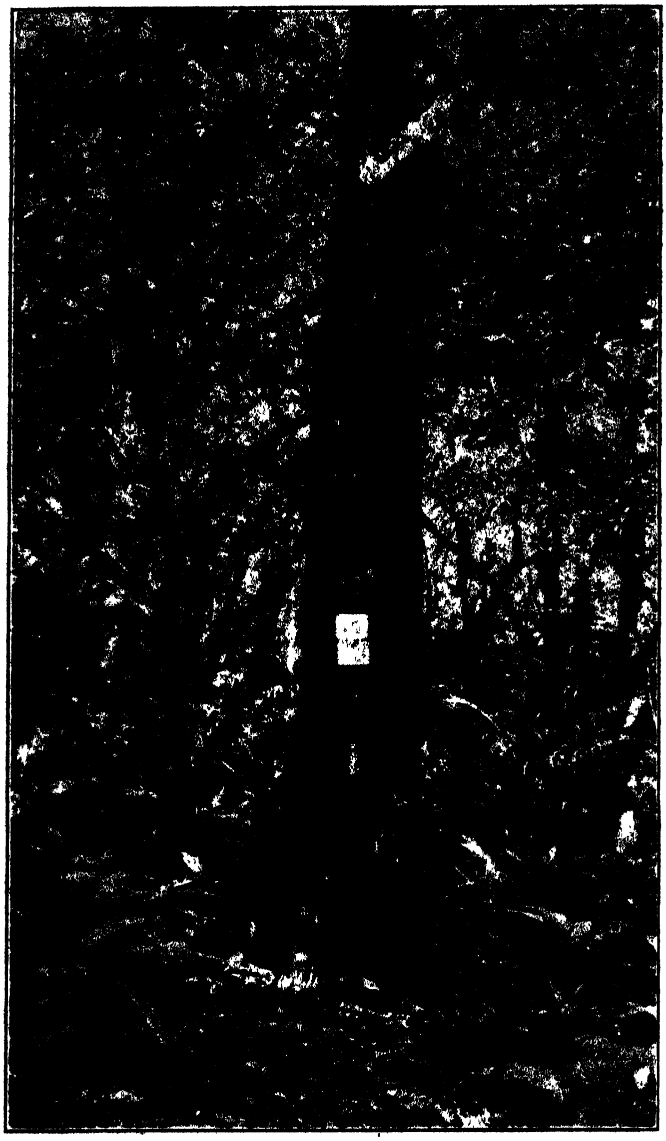
gata, reaching a height of 80 feet, with a trunk diameter of about four feet; *Ficus ribes* is a smaller species, and so are *Ficus alba. Ficus cuspidata,* and *Ficus rostrata,* of all of which the writer brought back quantities of seed. Especially common was *Ficus variegata,* which has a fruit nearly the size of the ordinary Smyrna fig, and which is said to be edible.

The most striking of all trees in this region is the Rasamala tree *Altingia excelsa,* the tallest forest tree of Java; the tree is very common in this region, so that one can speak of a Rasamala zone. The tree reaches a height of 180 feet or more, forms straight boles 120 feet in height before the first branches occur; it towers above everything else in the forest. Seedlings were, however, very scarce and very few young trees were noticed. The old trees are said to fruit very rarely, which accounts for the small number of seedlings. Two trees were



A Rasamala tree, *Altingia excelsa*, in the second zone, covered with epiphytes lianes, etc. The tree reaches diameters of over six feet.

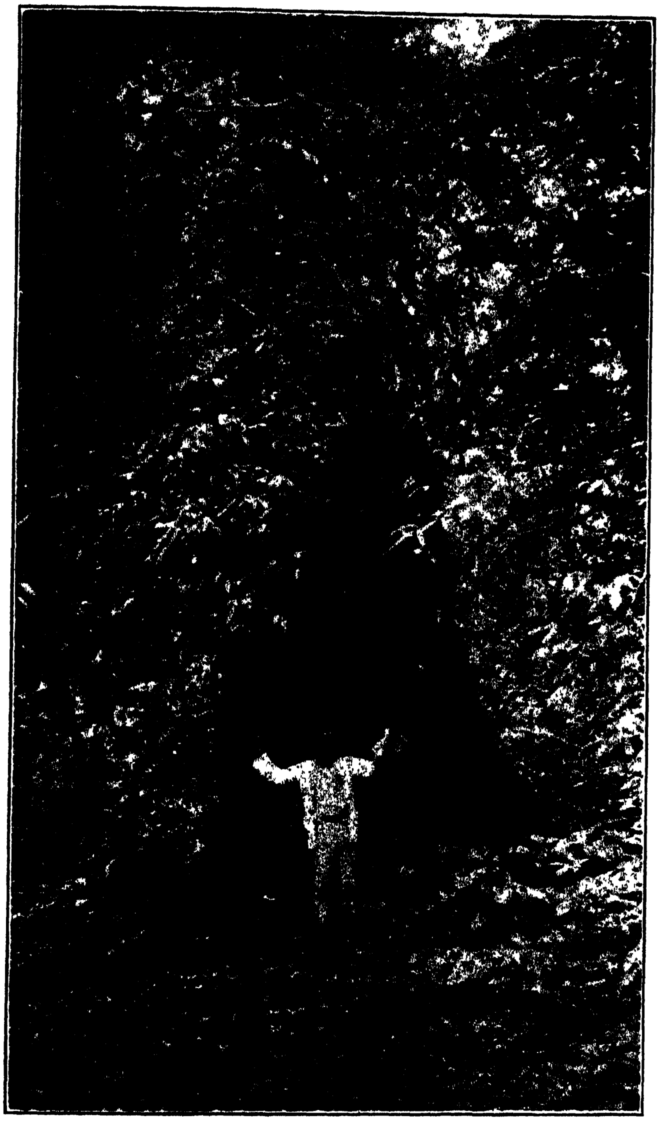
found bearing fruits, but they were still immature and would not be ripe till October. The trunks of Altingia trees are usually from five to six feet in diameter or even more. The writer arranged to have seed of this fine species collected when mature and to have same shipped to Hawaii. The Laurel family is represented by species of *Litsea* as *L. angulata*; associated with it are *Ilex cymosa, Eugenia tenuicuspis, Pandanus laevis, Manglieta glauca* or *Magnolia Blumei,* the latter a synonym of the former. The most striking and numerous trees next to *Altingia* are species of Chestnuts, of which *Castanea javanica* is the most common. It was in full fruit, and the writer kept nine men collecting seeds of that species alone for nearly a week. *Castanea tungurut,* also a large and handsome species, is less numerous and was not in fruit this year; the keeper of the gardens remarked that it bore abundantly the year before and the seeds



Tree No. 8898, *Vernonia arborea* Hmlt. It belongs to the Sunflower family (*Compositae*) and is over sixty feet in height and is nearly twenty-nine inches in diameter. It belongs to the Rasamala zone, 4600 feet elevation. The smaller stems to right are *Tetrastigma papillosum.*

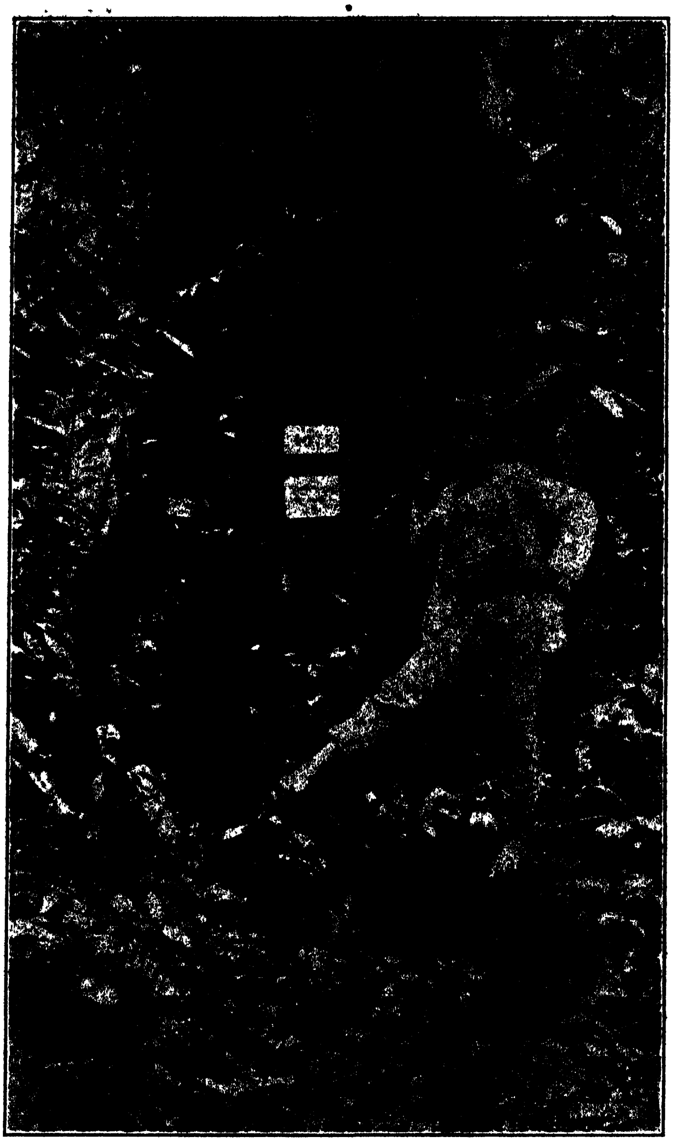
were sent down to the markets, where they were sold in large quantities. Species of *Saurauja* form smaller forest trees; they are very conspicuous on account of their large pendulous whitish flowers. *Elaeocarpus ganitrus* and *E. dentatus* occur also in this zone with *Toona febrifuga,* a meliaceous tree of which large specimens can be found in Honolulu in Mrs. Foster's grounds on Nuuanu Avenue. A very remarkable tree is *Vernonia arborea,* belonging to the Sunflower family; it is not uncommon in this region, and trees a hundred feet in height and trunks of three feet in diameter are not uncommon (see plate).

The undershrub in this zone is mainly composed of zingiberaceous plants; a species of *Impatiens* is common. *Amomum, Elatostemon,* an urticaceous plant, and a few palms as *Plectocomia* and *Calamus,* both climbing species,



Ficus involucrata Bl. This fig tree is 150 feet in height and nine feet in diameter. It is a rival of the Rasamala tree.

while *Pinanga Kuhlii* is the only erect palm present. It ascends, however, into the third zone. Its aspect is quite different from the cultivated plants in the gardens. Of other climbing plants belonging to this region are *Rhapidophora* and *Scindapsus, Nectandra angustifolia,* of which the writer secured an abundance of seed; also *Leea sambucina,* which, while not a real climber, is here a shrub with exceedingly long intertwining branches twenty to thirty feet in length. One species of *Freycinettia,* related to our *F. arborea,* the *Ieie* of the Hawaiians, festoons the trees, but not to the extent of our species in Hawaii. The most remarkable epiphyte is the Bird's Nest fern *Asplenium nidus* (see plate), which festoons most of the trees and ascends to an elevation of 6000 feet, while in Hawaii it rarely goes up to 1000 feet. Only a single apparently wild species of Bamboo ascends into the second or Rasamala zone. Epiphytic ferns are very numerous, especially interesting being *Pleopeltis heraclea,* on the



Tree No. 3073, ***Podocarpus imbricatus*** Bl. (Syn. *P. cupressina* R. Br.) This conifer is 110 feet in height and nearly five feet in diameter. It is less common in the Rasamala zone.

lower edge of the second zone. Of orchids we find *Dendrobium, Bulbophyllum, Appendicula,* etc.

Other trees worthy of mention as occurring in this region are *Engelhardtia spicata,* belonging to the Walnut family; *Trema orientalis,* to the Elm family, and two huge climbing rutaceous plants with stout spines, *Fagara scandens* and *Toddalia aculeata.*

The Third Forest Zone by Tjibeurum and Kandang Badak.

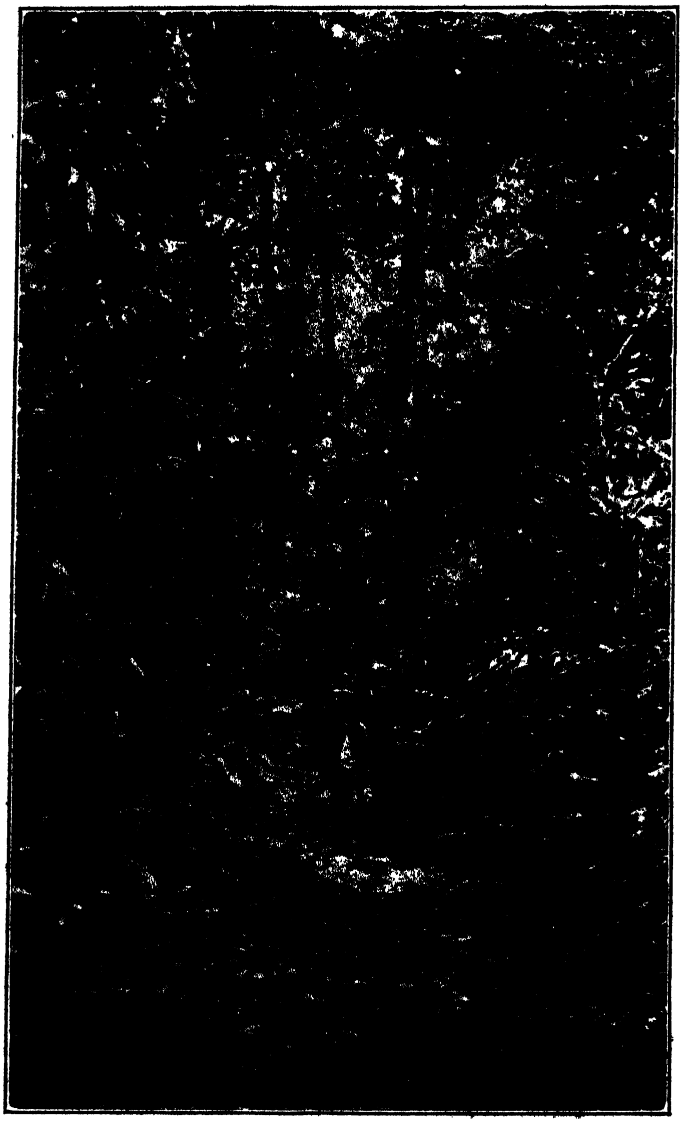
As we ascend from the Rasamala zone upwards we find that Castanea is absent and its place is taken by several species of Oaks (*Quercus*) and Conifers of the *Taxaceae, Podocarpus imbricatus, Podocarpus amarus* and *Podocarpus neriifolius.* The first mentioned species reaches the highest dimensions and is

Tree No. 3191, *Litsea angulata* Bl. A member of the Laurel family; it is nearly 60 feet in height and over two feet in diameter.

the rival of the Rasamala tree; it reaches a height of 160 feet and a trunk similar to that of the Rasamala. It is also very numerous, so that one could speak of the *Podocarpus* zone. Associated here with it are *Pithecolobium montanum*, one of the few arborescent leguminous trees found on Gedeh; several species of Litsea of the Laurel family, members of the family *Melastomaceae*, as, for example, *Memecylon*, are not uncommon. Here also belongs the rutaceous tree *Acronychia laurifolia*, the cunoniaceous *Weinmannia Blumei*; the latter is, however, not common.

Of Euphorbiaceae we find *Homalanthus populifolius*, with leaves resembling a poplar; an *Antidesma*, and others.

The tree ferns reach here their best development, and fine, handsome tall specimens can be found. They belong to the genera *Cyathea* and *Alsophylla*, the latter represented by *A. glauca* var. *densa*, with specimens of over fifty feet



Showing the trail in the rain forest leading into the Podocarpus belt; ferns are here very numerous; in the foreground Sapiin, the well known Javanese plant collector who knows the native names of most of the plants in this forest reserve.

in height. One of the commonest and finest forest trees next to *Podocarpus* is *Schima Noronhae*, the *Poespa* tree of the natives; it does not only occur in the third forest zone, but descends to the second zone and ascends away into the fourth zone. It is one of the most promising trees, owing to its indifference to climatic conditions. Unfortunately the *Poespa* trees were in full bloom at the time of the writer's visit, but arrangements were made to have seeds of that species sent to Hawaii as soon as available. The forest floor was literally strewn with the handsome large white flowers of the *Poespa*, a member of the Thea family.

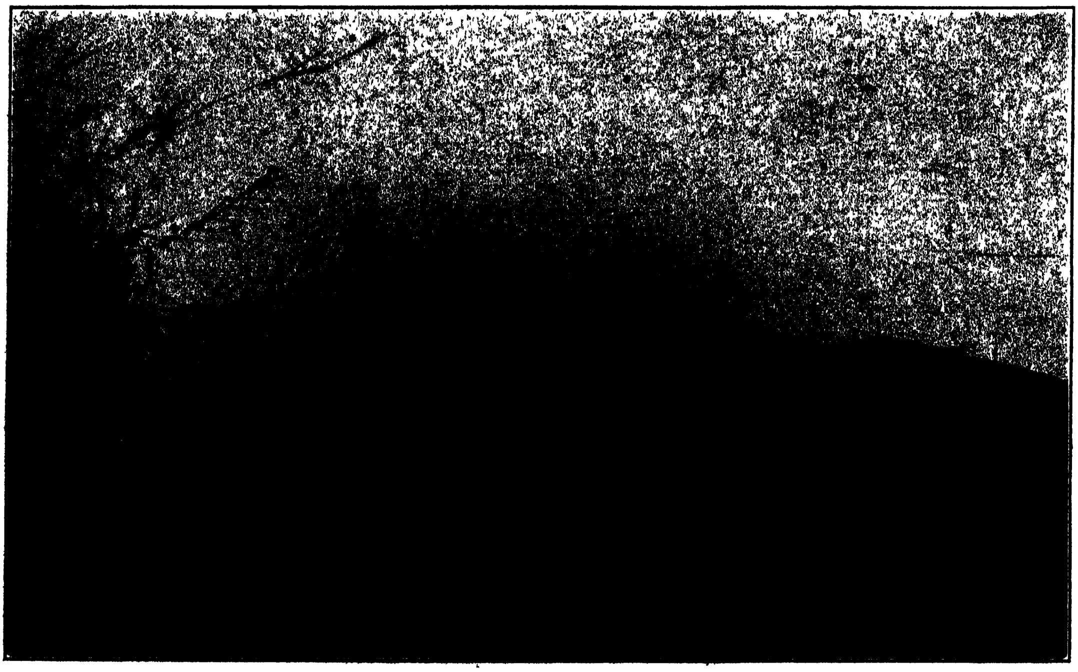
Melastomaceae are common—especially fine trees of *Astronia* may be found, besides *Medinella* and others. Smaller plants and shrubs as well as small trees are very common, and the most conspicuous are *Perrottetia alpestris*, the myr-

Bird's nest ferns, *Asplenium nidus*, on *Memecylon*, a tree belonging to the *Melastomaceae*. Other trees in this forest are *Castanea javanica*, *Cedrela*, *Ficus ribes*, etc. The palm *Pinanga Kuhlii* Bl. with pinnate leaves can be seen in the lower part of the picture.

sinaceous species *Rapanea affinis*, *Ardisia javanica*, and others. *Schefflera scandens* is a climbing shrub; *Rhododendrom javanicum*, a gorgeous plant with large orange-red flowers, grows both terrestrially and epiphytically on other trees. Of Urticaceae we still find a species of *Elatostemon*, which covers the walls at the Tjibeurum Waterfalls. Here we still find Bananas (*Musa acuminata*) and the zingiberaceous *Hornstedtia paludosa*. The undergrowth is now mostly composed of a liliaceous plant, *Disporum pullum*, which forms a dense cover. It dies down after producing numerous large lead-blue fruits. Remarkable plants are *Begonia robusta*, *Cyrtandra picta* and *C. grandis*. This region is also the home of *Gunnera macrophylla*, of which Hawaii possesses a close relative, the *Apeape* of the natives, *Gunnera petaloidea*; only the Hawaiian species excels the Javanese species greatly in size of leaves. Orchids to the

number of 150 clothe trunks of trees; also mosses and liverworths find here their best development. The genus Rubus is here represented by two species, *R. lineatus,* with red, delicious fruits, and another species with yellow fruits less delicious. *Schefflera rigida; Aralia ferox, Rumex crispus* and herbaceous composites belong here also.

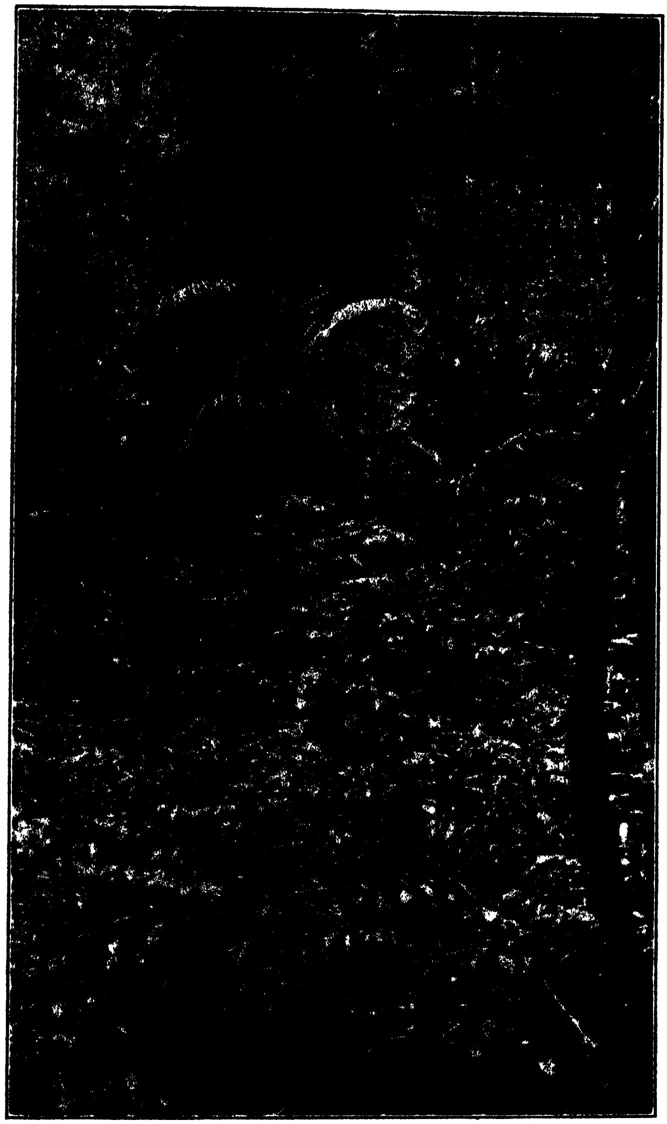
The *Ericaceae* reach here a remarkable development For example, *Vaccinium Theysmannii,* related to the Hawaiian Ohelo berry (*Vaccinium reticulatum*), becomes a liana and was observed by the writer climbing a tall Podocarpus trunk in the moss forest to a height of nearly 80 feet (see plate). *Vaccinium*



Mt. Pangerango as seen from the trail to Tjibeurum, Mt. Gedeh. The grass is an *Imperata,* or Lalang grass, a great and dangerous enemy to the forests, like our Hilo grass (*Paspalum conjugatum*), only worse.

varingiifolium, usually densely covered with moss and epiphytic ferns, reaches here a height of nearly 50 feet, with a trunk of about two feet in diameter. Another genus represented here is *Gaultheria* by the very fragrant *Gaultheria fragrantissima.*

Of herbaceous plants we find a plantain, *Plantago Hasskarlii,* buttercups as *Ranunculus diffusus, R. javanicus, Sanicula europaea*; and of ferns we find species of *Lomaria, Elaphoglossum callifolium, Oleandra neriiformis,* the latter usually a climber. *Pleopeltis Feei* covers open rocky places as near the waterfalls of Tjibeurum, and the epiphytic *Polypodium obliquatum,* which reminds one very much of our *Polypodium adenophorum.* *Hedychium Roxburghii* belongs still in the Podocarpus belt as *Melastoma aspera, Viola serpens,* a small but pretty native violet, and two or three lobeliaceous plants, as *Pratia montana,* with large pale purplish berries and handsome pale blue flowers; also *P. nummularia,* and a climbing species of *Campanumoea* (*javanica*) with carmine berries. The most common orchid, a very beautiful species of *Dendrobium* (*D. Hasseltii*), with purple flowers, festooned the moss-covered trees. The writer



Rain forest on Mt. Gedeh; the slender palms are *Pinanga Kuhlii* Bl. The underbrush is *Strobilanthus cernua;* on the trees, *Asplenium nidus*, the bird's nest fern. Trees are *Nauclea, Schima,* etc.

spent three days at Kandang Badak, a rest-house erected by the Government for visiting scientists. This rest-house is situated at 7400 feet elevation, and consequently the temperature is quite low, especially during the night. The ascent of Mt. Gedeh is made from Kandang Badak. The trail becomes steeper and the moss forest more open; underbrush is scarcer. The trees are of much smaller stature; the predominating species are still *Podocarpus imbricatus, Schima Noronhae,* an occasional Oak or *Quercus,* but the most common species is the Ohelo berry tree, *Vaccinium varingiifolium. Albizzia montana* makes its appearance now for the first time, the moss becomes scarcer, the trees thinner and more straggly as we ascend.

Hypericum Hookerianum was observed as an epiphyte. *Viburnum coriaceum, Schefflera divaricatum* join the other plants mentioned; also *Melastoma*

On the way to Tjibeurum Falls; a little brook in the woods. The trees are *Schima, Quercus, Elaeocarpus.* Of climbers we find *Freycinetia, Agalmyla parasitica,* etc. The trees are festooned with orchids.

setigerum. Vaccinium forms now almost pure stands. They are spindly, small trees till we come to the saddle of Gedeh crater.

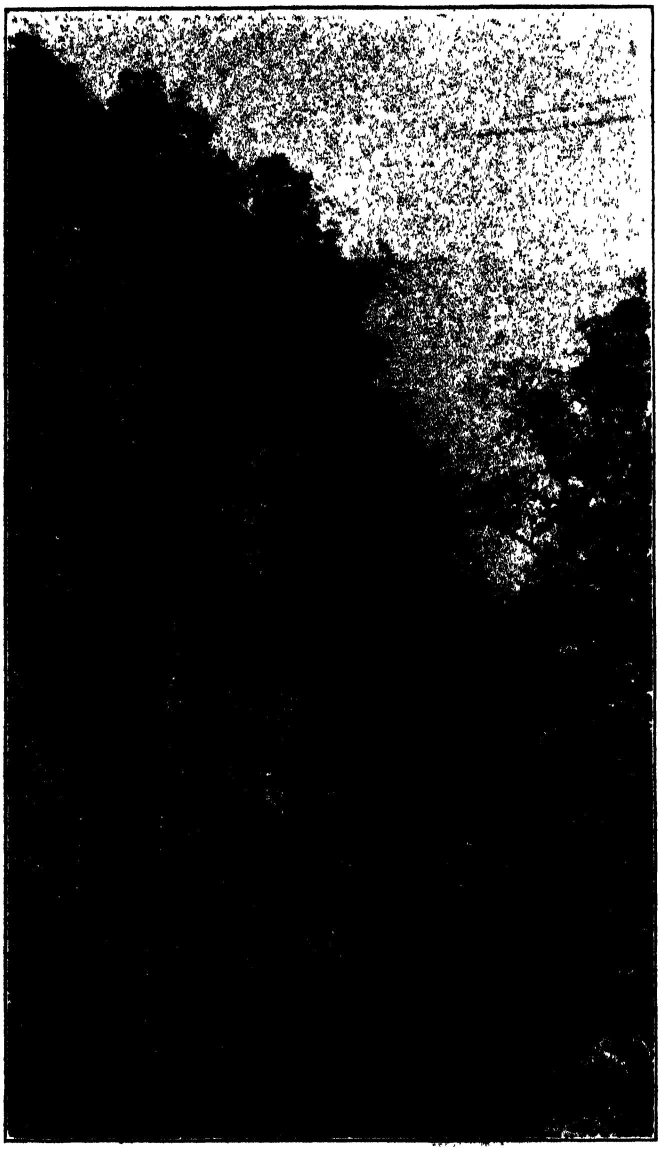
The trail descends now and we behold for the first time the Javanese Edelweiss *Anaphalis javanica,* a beautiful shrub or small tree with white woolly lanceolate leaves belonging to the Compositae. *Albizzia montana,* a beautiful small tree (up to 45 feet in height), with bright yellow flowers arranged in dense spikes, is now the commonest tree. It is associated with *Vaccinium varingiifolium, Gaultheria fragrantissima,* the two latter belonging to the Ohelo berry family. Another handsome tree is *Myrica javanica,* which can only be found in this open alpine region. Of rushes, mention must be made of *Gahnia javanica,* which grows among basaltic lava rocks. *Lycopodium Gedeanum,* resembling much the Hawaiian *Lycopodium cernuum* (*Wawaiole*), is a creeper near

Agaimyla parasitica, an interesting plant with large red flowers, belonging to the *Gesnera* family. In the cool of the morning the leaves stand at right angles to the trunk, but in the afternoon they droop. *Freycinetia* can be seen to the right; bird's nest fern on the trunk.

the summit of Gedeh, while at the summit proper, among the rocks, the writer found two species of Gaultheria, one *G. leucocarpa,* with snow-white fruits, a small handsome bush; and the other a small creeper with blackish purple fruits, viz: *Gaultheria nummularifolia.*

The Crater of Gedeh itself showed not much activity; according to statistics it was last in eruption in 1840 and 1886. All that could be seen was steam arising from the wall of the crater, while the floor was smooth and looked like dried mud. Evidences of it being very much alive can be seen in the mossy forest zone, where several boiling hot springs gush forth from the mountain side, which collect into a stream and form the three waterfalls at Tjibeurum.

The Crater of Gedeh is not very large and is only about 200 feet deep.



Forest near Tjibeurum, a typical rain forest of *Quercus, Acronychia laurifolia, Engelhardtia spicata, Schima Noronhae*, etc. The undergrowth is composed of ferns, *Strobilanthus, Impatiens, Carex baccans*, etc.

A wonderful panorama unfolds itself at the top of Gedeh, with clouds at one's feet and the mountain peak of Pangerango to the left, that of Goenoengsela to the right and others in front overlooking the broad plain which descends from here to the foot of the mountain. Just below the summit and near Goenoengsela are many fumaroles or sulphataras.

As has already been stated, the writer collected and caused to have collected seeds of trees from all the different forest zones here described. The list is too long to mention the species here, and as a matter of record it will be published elsewhere.

In conclusion, the writer cannot help remarking about the wonderful care given by the Dutch Government to this reserve. The forests of Gedeh have

One of the three waterfalls of Tjibeurum. A thousand feet or so higher this water comes out of the ground boiling hot, but is cold when it reaches Tjibeurum. The plants along the wall are ferns and a species of *Elatostemon.*

been made easily accessible through well-kept trails, and there is not a second tropical forest which has been visited in the last decade by so many naturalists from all parts of the world. Gedeh is not the only Nature Monument set aside by a wise government in Java; a number occur and are distributed throughout the Island. They have not only been set aside, but are assiduously studied by foresters, botanists and biologists. Trails dissect the mountain slopes in several directions, and it is along these trails that trees are labelled with their scientific names and numbers. A map of this forest region is about to be published, showing these trails and the location of the various marked trees along the trails. A list has been published of these trees, and one need only refer to the number in the list, which furnishes all available data about that particular tree since 1890.

Gunnera macrophylla and *Cyrtandra picta*, near the foot of the larger of the three falls at Tjibeurum. Like the Hawaiian *Gunnera petaloidea*, this species also loves the sprays of waterfalls and rocky cliffs.

No trees are allowed to be felled, and the collecting of plants is permitted for scientific purposes only. While the forests have been more or less thoroughly explored, still visiting botanists have every now and then discovered new plants or plants not previously recorded from Gedeh. Many eminent biologists have visited Gedeh and each carried on his or her particular line of investigation, with the result that there is a volume of literature on the forest of Gedeh and West Java proper which have enabled the Government to care for their forest reserves in the most scientific and efficient manner. While they have expended and are expending large sums of ~~money~~ for the upkeep of their gardens, laboratories and living quarters for visiting scientists, they have reaped untold benefit by the investigations carried on by both their local and visiting scientists.

In the Podocarpus forest. The tall tree is *Podocarpus imbricatus* associated with Poespa—*Schima Noronhae*, *Quercus induta*, etc. Occasional bird's nest ferns are still prevailing in this region.

Such a nature monument it would be wise to establish in Hawaii, and there should be formed a society for the protection of our forests, whose aim should be the establishing of nature monuments under government supervision.

Trails should be cut properly and not promiscuously by private individuals without supervision, and rest-houses established with facilities for scientific work.

We may well learn a lesson from the Dutch Government in proper forest management. By adopting similar methods we would attract scientists from all parts of the world, especially from our mainland institutions of learning, as the Hawaiian Islands are more easily accessible than Java, in the southern hemisphere.

Cyrtandra grandis in the moss forest, 6500 feet elevation. It is not very common and does not descend into the Rasamala forest. It is one of about eighteen species occurring in Java, one of four found on Gedeh; in Hawaii we have about ninety species and varieties of this genus; they are all members of the rainforest.

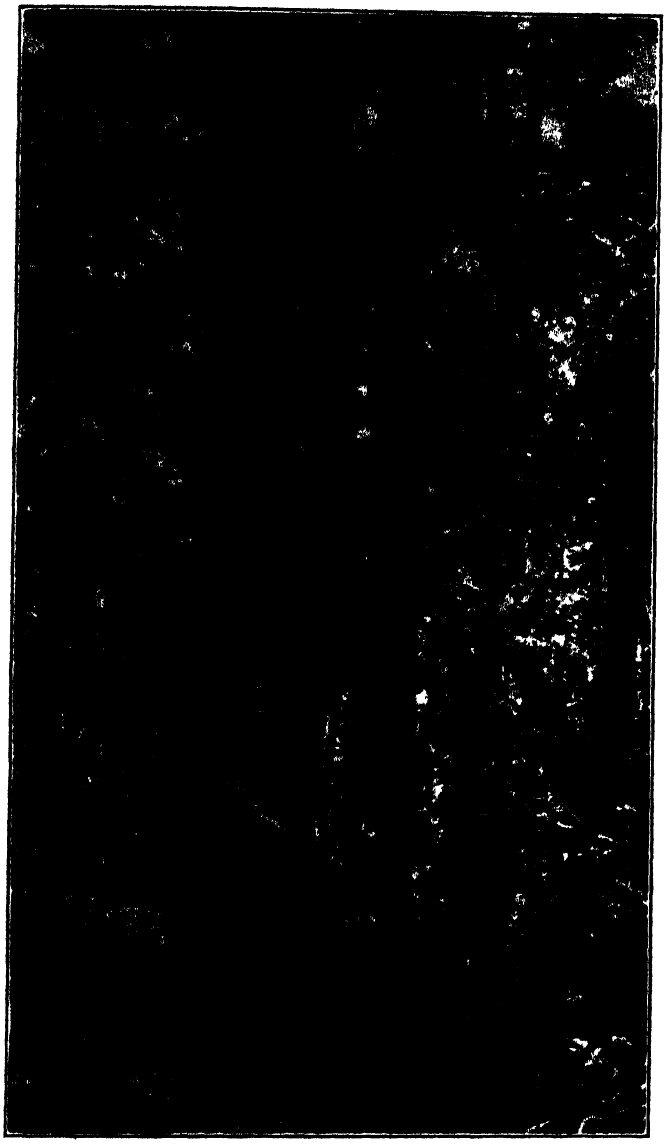
SYNOPSIS OF THE MORE IMPORTANT PLANT FAMILIES OCCURRING ON GEDEH AND THEIR RELATIVES IN HAWAII.

GYMNOSPERMS.

The Taxaceae is represented on Gedeh by three species, of which *Podocarpus imbricatus* is the most common. In Hawaii Gymnosperms are entirely absent.

MONOCOTYLEDONES.

Of *Pandanaceae* (Pandanus family), *Pandanus lais* occurs in the second



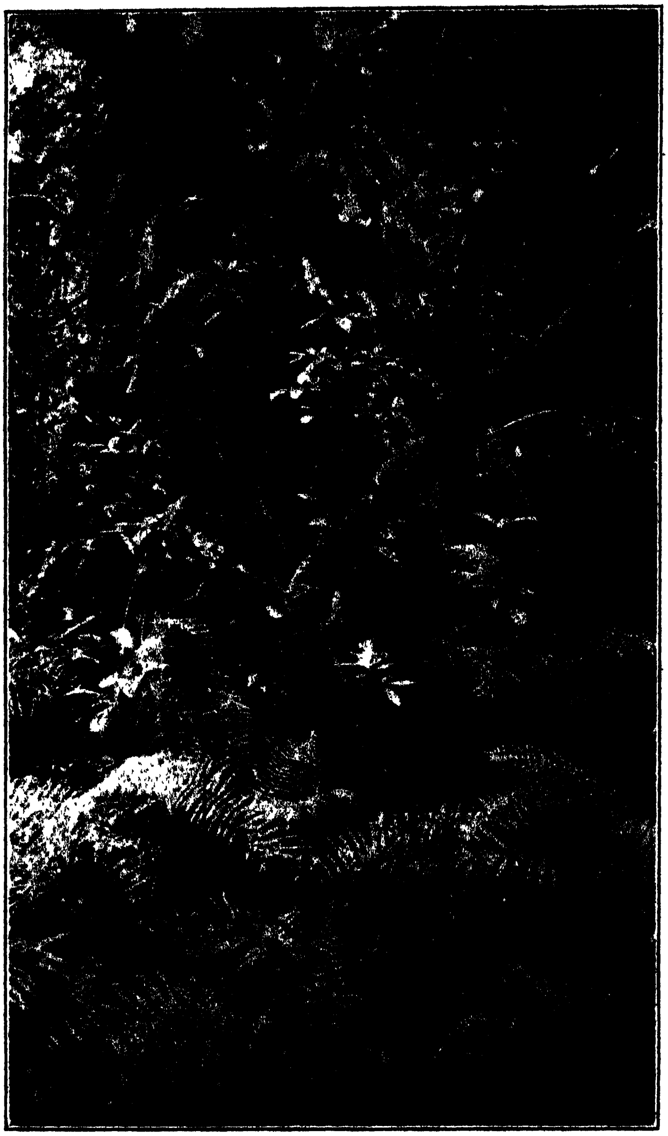
Dense moss forest 7000 feet elevation. The large trunk to the left is *Podocarpus imbricatus*, covered with moss; the stout liane climbing up the trunk is *Vaccinium Teysmannii*; it ascends eighty feet into the crown of the tree; it belongs to the Ericaceae and to the same genus as the Hawaiian *Ohelo* berry.

forest zone. In Hawaii the genus is represented by one species, *Pandanus tectorius,* but with four varieties, none of which go higher than 1000 feet.

The genus *Freycinetia* is represented by two species on Gedeh, *F. insignis* and *F. javanica,* while in Hawaii we find only one species widely distributed through our archipelago (*F. arborea*).

Of *Gramineae,* grasses are only sparingly found on Gedeh and are absent in the upper forest.

A *Bambu* (*Dinochloa scandens*) occurs in the second, but goes also into the third zone on Gedeh. In Hawaii we have only one Bambu (*Bambusa vulgaris*), which is restricted to the lowlands.

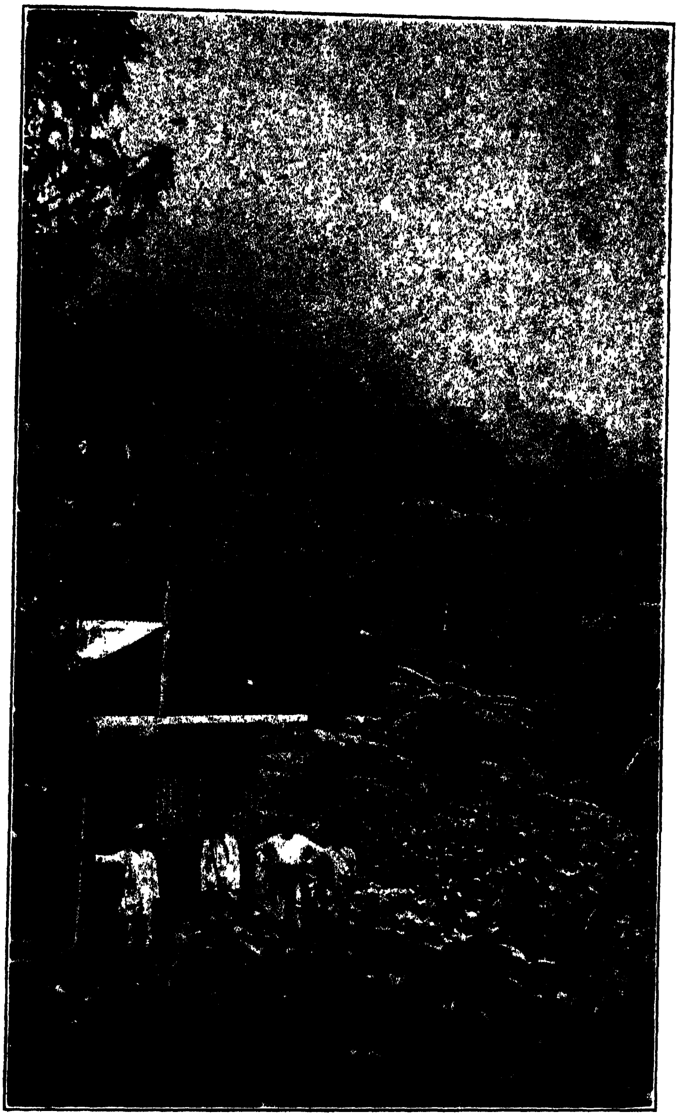


Trunks of *Vaccinium varingiifolium*, the Javanese "Ohelo" berry tree. Trees fifty feet in height and two feet or more in diameter are not uncommon. The fern in the foreground is *Lomaria vestita*; on the moss-covered trunk *Elaphoglossum callifolium*. The trunk to the extreme right is *Podocarpus imbricatus*.

Of *Cyperaceae* or rushes only few are found on Gedeh, especially common being *Carex filicina* and *Carex baccans*; *Gahnia javanica* occurs near the summit in the alpine region. In Hawaii *Carex* occurs in the lower forest zone and up to, or over 5000 feet in the swamp forests. *Gahnia* is represented by several species, one *Gahnia* (*Beechey*) resembling *Gahnia javanica*. Some of the Hawaiian species are dry-district plants, and one or possibly two occur in the high swamp lands.

Of Palms we find on Gedeh only pinnate-leaved species, none of which have any relatives in Hawaii, where the fan-leaf type (*Pritchardia*) only occurs.

The *Araceae* or *Aroid* family is sparsely represented on Gedeh with the exception of two root-climbers of the genus *Rhapidophora*. Hawaii has none.



Kandang Badak rest house at an elevation of 7500 feet. From here the summit of Mt. Gedeh can be reached in about two or three hours. *Alsophylla* tree ferns, *Urticaceae*, *Astronia spectabilis*, *Viburnum coriaceum*, *Melastoma setigerum*, etc., from the trees and shrubs. In the extreme lower left on the wall is *Rumex crispus*. Two species of Rubus occur here also.

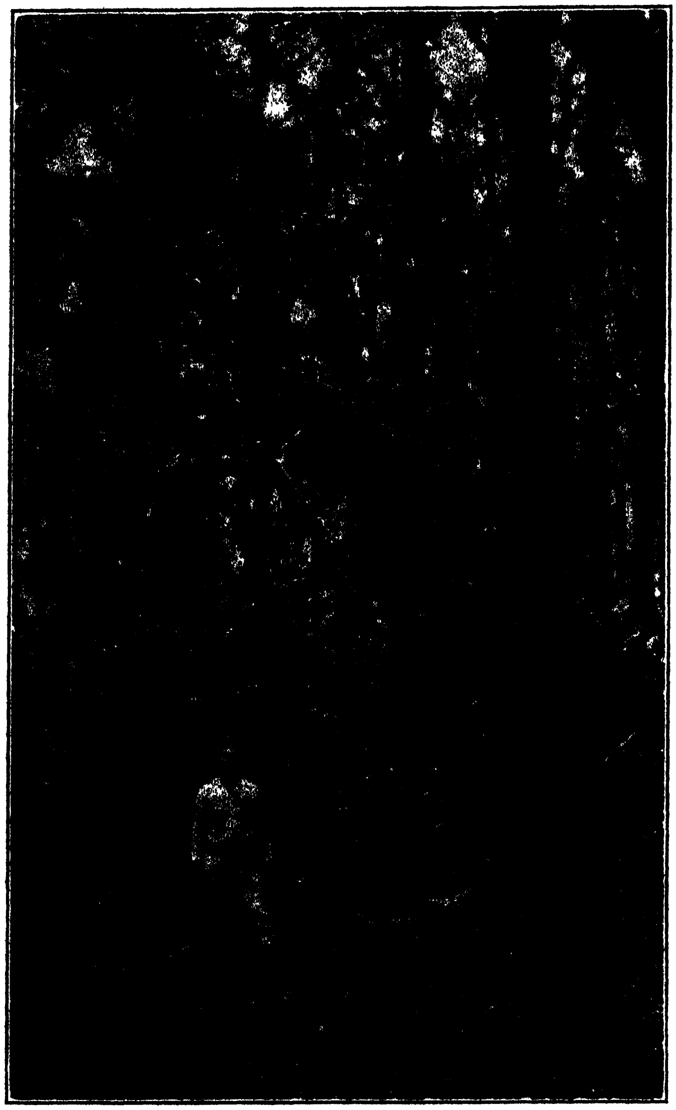
The *Commelinaceae* have five species on Gedeh, of which one, *Forestia glabrata*, is common. Hawaii has none or only the introduced *Commelina nudiflora*, the *Honohono*.

Of *Liliaceae* (Lily family), *Disporum pullum* is the commonest species and forms pure stand as undergrowth, and dies down after fruiting.

In Hawaii no relatives of that genus are present.

Dianella occurs both on Gedeh and in Hawaii, but is represented by different species.

Of *Musaceae* (Banana family), only one species (*M. acuminata*) occurs on Gedeh; in Hawaii *M. sapientum* is represented by many non-seed-bearing native varieties in similar locations as *M. acuminata* on Gedeh.



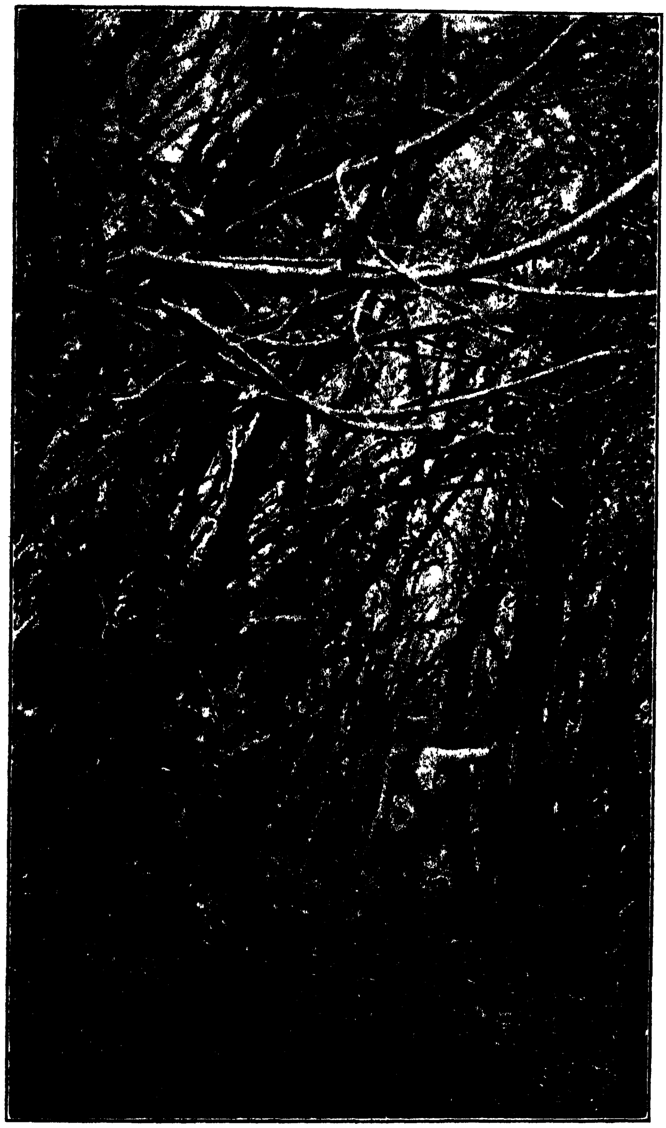
Moss forest with smaller trees at nearly 7800 feet elevation. The trees are *Vaccinium varingiifolium*, *Schima Noronhae*, *Elaeocarpus*, *Melastoma setigerum*, *Schefflera*, *Viburnum*, etc. The beautiful orchid *Dendrobium Hasseltii* with purple flowers is very common in this cold, foggy region.

Zingiberaceae or ginger family is represented by numerous species in the lowlands but only by few species in the third zone. Hawaii has only one zingiberaceous plant, namely, *Zingiber zerumbet*, peculiar to the lower forest zone.

Of *Orchidaceae*, Gedeh possesses 150 species, the majority of which are epiphytes, while only a few are terrestrial. *Dendrobium* is represented by 20 species, *Bulbophyllum* by 15, *Apendicula* by 6, *Liparis* by 8. Hawaii is exceedingly poor in orchids and possess only three genera, of which each is represented by a single species. The genera found in Hawaii are *Liparis*, *Anoectochilus*, and *Habenaria*.

DICOTYLEDONES.

Of *Piperaceae*, two species of *Peperomia*, of which one, *P. reflexa*, occurs



The last stands of trees, mostly composed of *Vacciniums, Kimarak,* and *Ganapura.* Note the absence of moss.

also in Hawaii, ascends into the third region. Hawaii possesses over 75 species of *Peperomia,* while *Piper,* which is represented by three species on Gedèh, is only represented by the cultivated species *P. methysticum.*

The *Juglandaceae* or Walnut family has two species of *Engelhardtia* on Gedeh. In Hawaii the family is unknown.

The *Fagaceae* or Chestnut family has nine species of oaks and three species of chestnuts on Gedeh; in Hawaii the family is absent.

To the *Ulmaceae* belong three species of the third and first zones; *Trema orientalis,* however, belongs to the first zone. In Hawaii we have *Trema amboinensis,* which is, however, very rare.

The *Moraceae* or fig family possess quite a number of species of *Ficus,* of

In the upper outskirts of the forest approaching the summit of Gedeh. The white plant in the foreground is *Anaphalis javanica*, the Javanese Edelweiss; the trees in the back are Vaccinium and Gaultheria fragrantissima; elevation about 9000 feet.

which *Ficus ribes, F. variegata, F. involucrata* and *F. alba* are very common in the second zone. Hawaii has none.

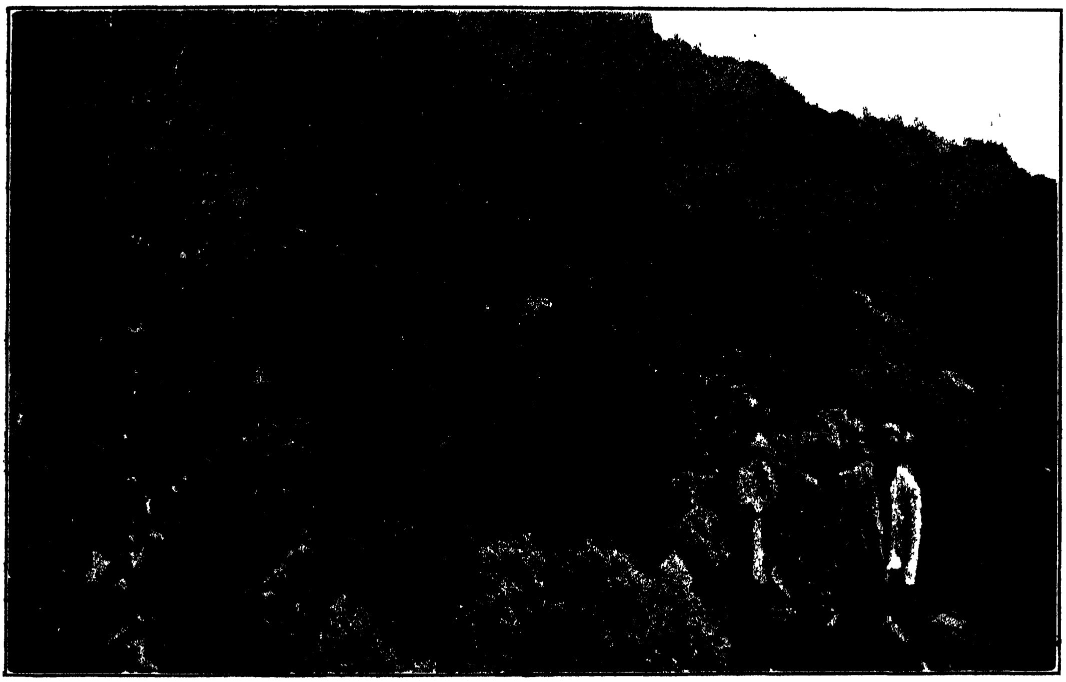
Of *Urticaceae* (Nettle family), the genera *Boehmeria, Pilea* are represented on Gedeh and in Hawaii, in the latter place each genus by one species. Other genera as *Elatostemon Debregeasia* and *Villebrunia*, etc., are found on Gedeh but not in Hawaii. Species of *Elatostemon* form the common undershrub in the Gedeh forest.

Of *Proteaceae* or *Grevillea* family only a ~~single~~ species (*Helicia serrata*) is found on Gedeh; in Hawaii the family is absent. Only a single species of *Henslowia* (*umbellata*) belonging to the *Santalaceae* occurs on Gedeh, while Hawaii possesses several species of *Santalum* and three species of *Exocarpus*.

The *Amaranthaceae* are represented on Gedeh by a few weeds restricted to the lower forest border; one of them, *Amarantus spinosus,* occurs also in Honolulu in waste places. Hawaii possesses a genus of trees belonging to this family.

Of *Ranunculaceae,* or Buttercup family, there are to be found on Gedeh two species of *Clematis* and two species of *Ranunculus.* The latter genus is represented in Hawaii also by two endemic species.

While the *Magnoliaceae* are absent in Hawaii, the family is represented on Gedeh by several species, important of which is *Magnolia Blumei.*



Near the summit of Gedeh. The trees are *Vaccinium, Gaultheria fragrantissima;* tree next to Javanese, *Myrica javanica,* and in the background, extreme right, *Albizzia montana.* The white plants in immediate foreground are *Anaphalis javanica.*

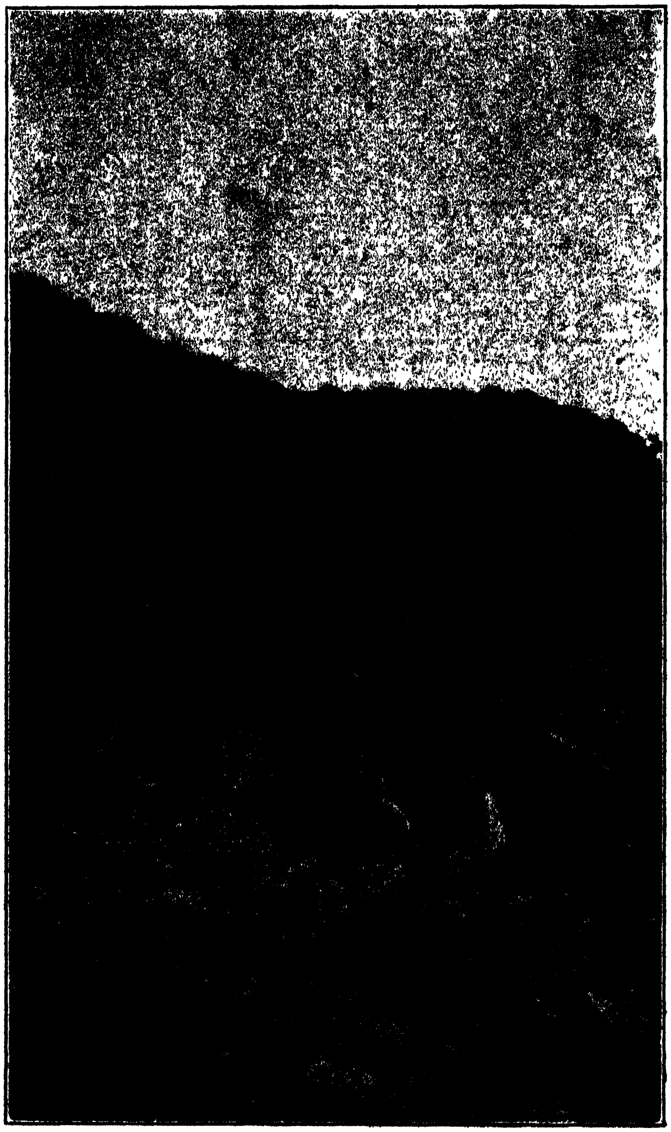
The *Lauraceae* form a very important plant family on Gedeh and are represented by sixteen species of trees, of which several reach large dimensions; especially noteworthy is the genus *Litsea.* In Hawaii there is only a single species of *Cryptocarya* to be found, and that only on the Island of Kauai, where it is known as "*Holio.*"

The *Pittosporaceae* are represented by a single tree, while Hawaii has quite a number of species of the genus *Pittosporum.*

The *Hamamelidaceae* have one tree species on Gedeh, the well-known Rasamala tree, the tallest tree in Java.

Of *Leguminosae* only two tree-species can be found, *Albizzia montana* and *Pithecolobium montanum.* Hawaii is also poor in *Leguminosae.*

The *Rutaceae* are scarce on Gedeh and are represented by one tree (*Acronychia laurifolia*) and two liana. Hawaii is rich in *Rutaceae,* as f. e. *Pelea,* related to *Acronychia, Zanthoxylum,* and *Platydesma.*



Albizzia montana, the most common tree on the summit of Gedeh. It is a handsome tree with large spikes of brilliant yellow flowers; elevation 9000 feet or more. *Anaphalis javanica* in the foreground.

The *Meliaceae* have four large tree-species, of which *Toona febrifuga* is one of the important ones. The family is absent in Hawaii.

Of *Euphorbiaceae*, only few species can be found on Gedeh, the most common forest tree being *Homolanthus populifolius*. Hawaii possesses many species of *Euphorbia*, two species of *Claoxylon* and two of *Antidesma* and others.

The *Aquifoliaceae* and *Celastraceae* have each one species on Gedeh belonging to the genera *Ilex* and *Perrottetia* respectively. The same genera are represented by one tree-species each in Hawaii.

The *Elaeocarpaceae* have several species of *Elaeocarpus*, as f. e. *E. stipu-*

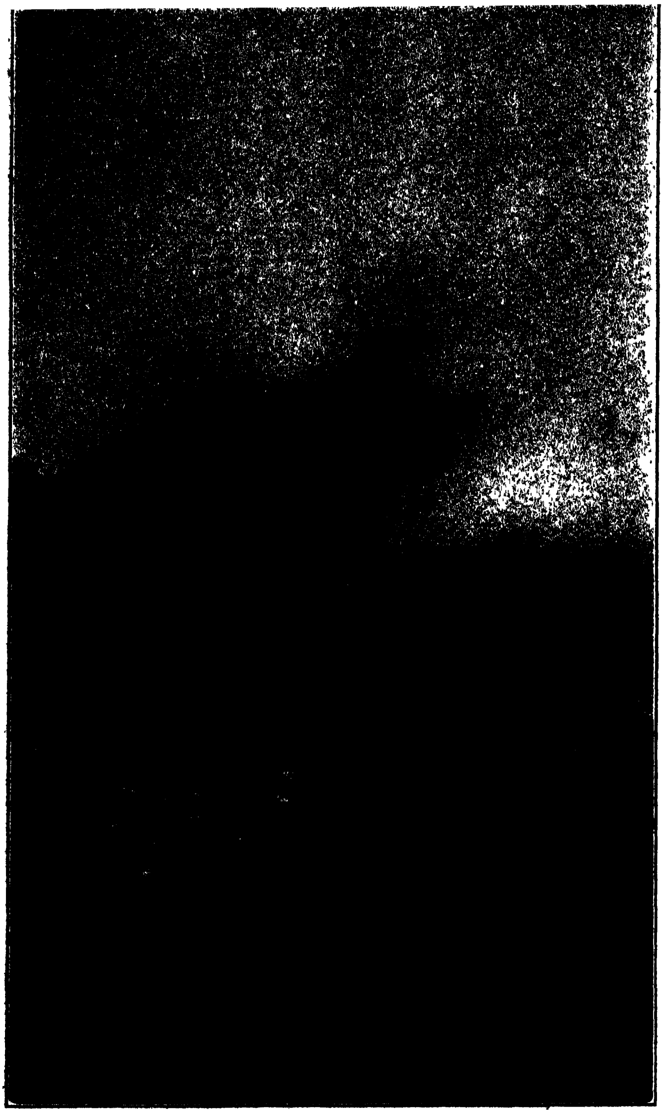
A rush, *Gahnia javanica*, near the summit of Gedeh. There are several species of *Gahnia* in Hawaii. Bushes in the background are *Gaultheria leucocarpa*, a white-fruited relative of the Hawaiian Ohelo berry.

laris, E. acronodia, E. ganitrus, etc. Hawaii has a single species, *E. bifidus,* peculiar to Oahu and Kauai.

The *Dilleniaceae,* while absent in Hawaii, are represented on Gedeh by seven species of *Saurauja* and *Actinidia callosa,* a rare climbing shrub.

The *Theaceae,* or Thea family, have three species of *Eurya* and the common *Poespa* or *Schima Noronhae.* Hawaii has a single species of *Eurya.*

The *Myrtaceae* possess a species of *Leptospermum* on Gedeh and several species of *Eugenia.* The latter genus is represented in Hawaii by a single species, but has two other species of that family belonging to genera closely allied to *Eugenia.*



Mount Pangerango with clouds seen from near the summit of Mt. Gedeh; elevation 3019 m.

The *Melastomaceae* have several species, noteworthy of which is the common tree *Astronia spectabilis.* Hawaii has no species belonging to this family.

The *Halorhagaceae* have two species of *Gunnera* on Gedeh, and one species of *Gunnera* in Hawaii.

The *Ericaceae* are important for Gedeh. One species of *Vaccinium* is a tree. In Hawaii there are several species of that genus, but all are shrubs. The genus *Gaultheria* has three species on Gedeh and one species of *Rhododendron*; both genera are absent in Hawaii.

The *Myrsinaceae* are represented by small trees of the genera *Ardisia* and *Rapanea.* Both genera are absent in Hawaii, but two other genera take their place in these Islands, *Suttonia* and *Embelia.*

Sulphataras on Mt. Gedeh, near summit. Mt. Goenoengsela in the background.

Of *Apocynaceae,* Gedeh has one species of *Rauwolfia* (*javanica*). Hawaii has also one species, *R. sandwicensis,* but possesses other genera belonging to this family, as *Ochrosia, Alyxia* and *Pteralyxia.*

The *Gesneriaceae* are represented by nine shrubs, the majority of which are *Cyrtandra.* This latter genus possesses many endemic species in Hawaii.

The *Rubiaceae* are represented on Gedeh by 27 species, of which five are trees. None of the shrubby or arboreous genera occurring on Gedeh are found in Hawaii, but these Islands possess numerous endemic tree-species belonging to endemic genera. The only rubiaceous plant common to both Java and Hawaii is *Nertera depressa.*

The summit crater of Mt. Gedeh, looking down into the pit. Sulphur fumes and steam rise from the different sides of the crater walls. The crater is about 200 feet deep; the floor is dry mud.

The *Lobeliaceae,* so rich in Hawaii, are represented on Gedeh by three or four herbaceous species, belonging to *Pratia* and *Campanumoea.*

The *Compositae* are also sparingly represented. Of note is *Vernonia arborea,* a large tree, and *Anaphalis javanica* of the alpine region. The family is richly represented in Hawaii by many arborescent endemic species of American affinity.

Spacing Experiments with Sugar Cane.*

In the December, 1918, number of "The Philippine Agriculturist" are reported the results of a spacing experiment with sugar cane. In conducting this test one plot only was used for each treatment. This lessens the value of results to a large extent; nevertheless, we consider them of interest, and herewith give a brief resumé of the work.

A level field with a clay-loam soil from which a crop of corn had been harvested was used for the experiment. This area was divided in fifteen plots, each measuring 4837 square feet.

The following table gives the methods of planting, the number of seed used and the number of stools, three months after planting and at harvest time:

No. of Plot	Width of Row in Feet	Spacing of Seed in Inches	No. of Seed Used per Acre	No. of Stools per Acre, 3 Mos. After Planting	No. of Stools per Acre at Harvest
1	1.64	end to end	32,375	22,240	8,435
2 †	discarded	....	.....	.....	....
3	2.46	9.84	10,791	7,194	5,971
4	3.28	end to end	16,187	10,396	4,955
5	3.28	19.68	5,396	5,045	4,497
6	3.28	29.53	4,047	3,876	3,615
7	4.92	end to end	10,791	8,211	3,804
8	4.92	19.68	3,597	3,480	3,381
9	4.92	29.53	2,698	2,671	2,662
10	5.74	end to end	9,227	5,558	4,227
11	5.74	19.68	3,068	2,572	2,572
12	5.74	29.53	2,307	2,158	2,158
13	2.56	9.84	10,198	7,248	6,259
14	2.46	19.68	7,159	7,167	7,158
15	2.46	29.53	5,382	5,360	5,333

† Plot No. 2 discarded on account of poor germination.

* By Josi Mirasol Y. Jison in "The Philippine Agriculturist."

The yields per acre for each plot are given as follows:

No. of Plot	Width of Row in Feet	Spacing of Seed in Inches	Yield per Acre		
			Cane	Q. R.	Sugar
1	1.64	end to end	36.6	9.1	4.04
3	2.46	9.84	29.3	8.7	3.37
4	3.28	end to end	33.6	9.8	3.42
5	3.28	19.68	26.8	8.2	3.27
6	3.28	29.53	26.2	8.4	3.10
7	4.92	end to end	28.8	7.5	3.84
8	4.92	19.68	26.2	7.9	4.44
9	4.92	29.53	32.3	9.5	3.45
10	5.74	end to end	23.9	8.5	2.82
11	5.74	19.68	17.9	8.5	2.57
12	5.74	29.53	24.3	9.2	2.64
13	2.56	9.84	32.5	7.6	4.30
14	2.46	19.68	26.6	7.3	3.65
15	2.46	29.53	36.0	8.8	4.07

In plot 1 the furrows were made with a native plow because they were too close together to allow the use of a double mould board. All plots except plot 1 received the same treatment. After three months, plot 1 would allow no further cultivation, and weeding was done by hand.

The cane was planted March 10-16 and harvested when twelve months old.

The article concludes as follows:

Indications are that:

1. The percentage of success in germination is lowest in the thick planting and highest in the thin; the percentage of mortality of the canes between the age of two months and the time of harvest is higher in the former than in the latter.
2. When planted closely, the cane has poorer chance to sucker than when planted farther apart, consequently smaller stools are obtained in the first case, and larger ones in the second.
3. In general, when planted closely the cane tends to grow high, but small in diameter; but, when spaced widely, it tends to gain in diameter rather than in length.
4. The damage to cane fields caused by rats was found to reach 25% of the total weight of the cane.
5. The greatest yield in tons of cane per hectare was obtained from the plot where the canes were planted 1.64 feet apart, seed end to end. The greatest yield in tons of 96° sugar per hectare was obtained in the plot where they were planted in lines 4.92 feet apart and seed spread 19.68 inches.
6. It is recommended that canes in this locality be planted at a distance of 4.92 feet by 19.68 inches. Aside from giving the highest yield of sugar per hectare, this spacing would save seeds, labor and time, and would allow the greatest amount of cultivation without much injury to the roots of the plant as a whole. The gain per hectare of plot where the distance was used over that where the native method was employed (plot 13) is 0.32 ton of 96° sugar, which amount would sell, at the present price, for ninety pesos.

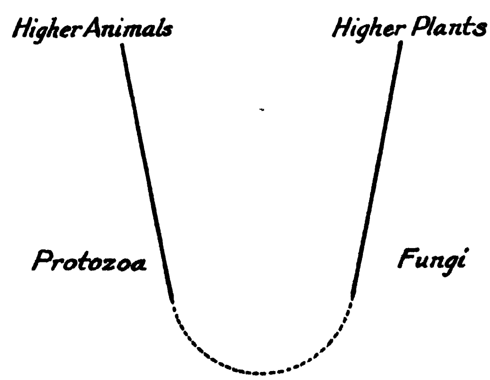
J. A. V.

Diseases of the Cane Plant.*

By E. L. Caum.

Disease in plants may be defined as variation from the normal physiological activity, which is sufficiently permanent to interfere with the plant's natural functions, and to check its development. The normal plant is in a state of equilibrium, based on the right amount of moisture, plant food, leaf surface to manufacture starch, etc. Anything which upsets this equilibrium will cause the condition which we know as disease. This upset may be due to one of three general causes—plant parasites, animal parasites, or adverse physical conditions. These talks will deal with the first class only—the diseases caused by plant parasites. The entomologists have covered the field of animal parasites, and the third class, that of physical conditions, takes in the whole field of fertilization, irrigation, cultivation, and the like.

To answer the question, "What is a plant parasite?" it is necessary to say something about the lower plants, or at least that group of them which we know technically as "fungi," and commonly as moulds, mildews, mushrooms, and the like. These plants, generally very small, differ from the higher plants, the trees, shrubs and the like, in that they do not possess chlorophyll. Lacking this chlorophyll, they are unable to elaborate their food from the raw materials, as the green plants do, and hence must obtain it ready-made. In this respect they resemble the animals, which likewise must get their food ready-made—in other words, steal it from some plant which has already manufactured it, or from some other animal. In the end, it goes back to the green plant as the original source of food for both animals and fungi. It should not be understood by this that the animals and the fungi are close relatives. They are not. except in a few cases, which I shall touch upon a little later. The fungi are the lowest forms of plant life, while the animals, or what we commonly know as animals, are well up the scale, on another branch.



Fungi are divided into two great classes, based on their form and manner of growth. These are the bacteria and the so-called mycelial fungi. The bacteria are single cells—independent units of plant structure. They reproduce by simply dividing in two, each half then being a complete and independent individual. The mycelial fungi are multicellular—that is, they are composed of many cells—in this one respect resembling the higher plants. Their structure in a general way resembles a mass of threads, called the mycelium. This mycelium forms special structures, the fruiting bodies, and in these the spores, or reproduc-

* A series of lectures presented at the Short Course for Plantation Men, October, 1919.

tive bodies, are formed. These spores are comparable to, although not idenfical with, the seeds of the higher plants. The fruiting bodies differ greatly in size and structure in different species of fungi, just as the seed pods of the higher plants do. The spores are produced in great numbers. In one of the puff-balls there have been estimated to be as many as seven million million (7,000,000,000,000), and each one of these, given the proper conditions, should germinate and produce a plant like the parent. The individual plants of the fungi with which we have to deal do not produce spores in anything like this number, but still they are sufficiently numerous for all practical purposes.

Another great division of the whole group of fungi is based on their manner of obtaining food, or rather on the source from which it is obtained. These are the saprophytes and the parasites. There are intermediate stages, but we need not be concerned with them now. The saprophytes are those which feed upon dead or dying organic matter. They are the scavengers of the fungus world. The parasites, on the other hand, attack healthy plants or animals, and draw their sustenance directly from the living host. It is with this latter group that we have to deal—with the fungi represented by the last quarter of the square, so to speak. There are a few bacterial parasites of the sugar cane, but they are not numerous, and the fungus diseases affecting the cane in these Islands are practically all due to mycelial fungi.

B. S.	B. P.
M. S.	M. P.

B = Bacteria.
M = Mycelial fungi.
S = Saprophytes.
P = Parasites.

As I said before, fungi must obtain their food ready-made, and from the cells of the host plant, in the case of the parasites, which are the ones with which we are chiefly concerned. This they do by the simple process of absorbing it, drawing the juices of the host plant through the cell walls and into their own bodies. Some parasites, which live on the outside of the host's body, and do not penetrate it, draw the juices through two cell walls, the wall of the host cell, and the wall of the fungus cell. Others simplify this process somewhat, by penetrating the body of the host, growing out between the cells and sending short branches directly into the host cells. This necessitates drawing the juices through only one cell wall, that of the fungus hypha, as the individual threads of the mycelium are called. Still others go this one better, and penetrate the cells of the host plant directly, living its life inside these cells, and not simply between them. These two classes are called external and internal parasites, or technically, ecto and endo-parasites. The important cane fungi are endo-parasites, the fungus penetrating the body of the cane plant.

Fungi are often specialized in one way or another. Thus some kinds will grow only when the host plant was previously healthy, others only when it was weakened from some other cause. Some will grow on only one host, others will attack many kinds of plants. Mostly they are local; that is, they attack only one part of the host plant. Some attack only the leaves, others only the roots. Others are not so particular—they are found in various parts of their victims. Most of

the parasitic fungi are local, and this holds good with the sugar-cane fungi. We rarely find these fungi outside their particular part. Thus we find leaf fungi on the leaves only, and root fungi only on the roots.

The ways in which fungi can injure plants is limited only by the number of functions the plant has which can be interfered with. Thus some attack the leaves, destroying so many of the starch-manufacturing cells that the plant cannot complete its development; others destroy the roots or clog up the vessels, cutting off the supply of food from the soil; others destroy the flowers or fruits, preventing the formation of seeds; while others set up a rot in some vital part, such as the base of the stem, causing a general collapse of the whole above-ground part. There is no part of a plant secure from attack, and there is scarcely one of its functions that cannot be seriously impaired.

And now, before we start a discussion of the specific organisms that cause disease in cane, I want to make a little comment. There is no such thing as a magic cure or a quick relief for fungus diseases of the sugar cane. Many of the plantation people think there is, and that it is our duty to furnish it. It is our duty to provide relief, in so far as we can, but in any case it is a long job. There is nothing in the whole history of plant pathology the world over that justifies the belief in a swift cure. Of course, we have to know the cause of a disease before we can intelligently contrive measures against it, but the corrective measures when devised must of necessity be in the nature of modifications of our agricultural practices. As a recent bulletin (No. 721) of the United States Department of Agriculture expresses it, "All plant pathological problems, from a practical standpoint, are closely connected with the cultural phases of crop production. Production cannot be successfully studied without a knowledge of the diseases affecting that particular crop, nor can the diseases of a crop be intelligently considered with reference to control measures except in conjunction with the cultural practices, and with a knowledge of the conditions under which the crop is grown." And consider this other point. Human pathology is about 50% curative, and 50% preventive. Animal pathology is about 10% curative, and 90% preventive. Plant pathology, especially sugar-cane pathology, by the very nature of things, must be at least 99% preventive. Here is another little list that tends to show the same point, and the whole history of plant pathology has developed no other means of combating plant diseases than these:

1. Quarantine against diseased plants and disease-carrying materials;
2. Cutting out and burning of diseased parts;
3. Destruction of diseased individuals;
4. Elimination of intermediary hosts (barberry in wheat rust);
5. Application of fungicides to seeds, cuttings, etc.;
6. Sterilization of the soil;
7. Application of iron salts in some cases of chlorosis;
8. Fallowing of the land;
9. Rotation of crops;
10. Correction of unsanitary soil conditions;
11. Adjustment of agricultural practices (cultivation, fertilization and irrigation).
12. Employment of resistant varieties.

Of these, the last one is the most desirable, from a commercial viewpoint, provided the variety substituted is as good as the one replaced. If you will keep these points in mind, you will understand better what I have to say about the individual diseases.

We will deal only with those diseases which are found in Hawaii. There are many fungous diseases in other sugar-growing countries, but as they have not appeared in the Islands, we need not discuss them at this time.

The first group of these, as the most obvious, and the most commonly seen in the fields, are the diseases of the *cane leaf.*

(1) *Eye-Spot.*

This disease, along with several other leaf diseases, is commonly referred to as "rust." This name is descriptive enough, but misleading. There is a cane disease, very prevalent in Java, that is properly known as "rust." This is caused by a fungus related to those causing the various cereal rusts, and very different from any leaf-spot fungus we have here. The eye-spot fungus, Cercospora Sacchari, is of wide distribution, and has been found all over the Islands. It is of rather common occurrence, and as a general thing does comparatively little damage, except when it becomes epidemic. In bright, sunshiny weather it is practically harmless, but when the weather gets warm and moist it will spread with great rapidity, and do considerable damage to the cane. The disease occurs mostly in makai fields, because of the atmospheric conditions in such localities. It first appears as a small light green or yellow spot, showing on both sides of the leaf. This soon becomes brown or reddish in the center, and as the spot becomes older this red streak extends on out toward the end of the leaf. The stripes seem to follow the fibro-vascular bundles of the leaf. The fungus does not grow out along this stripe; it is found only in the original spot. The fungus apparently secretes some sort of a poison which, being carried along the vessels with the sap, kills the cells with which it comes in contact. It is in this habit that the danger from the fungus lies. Thus, one fungus plant, originating from a single spore, will kill a strip of leaf tissue clear from the point where it happened to strike the leaf to the end of the leaf.

As to control measures, there are none in the proper sense of the term. Spraying, of course, is out of the question, and the solution in this case, as in several others, lies in resistant varieties. As Mr. Agee said the other day, there is a difference between susceptible and sensitive varieties. Most of our cane varieties are susceptible to this disease, but they are not all equally sensitive. H 333, for instance, which was at one time considered one of the best of the Hawaiian seedlings, is extremely sensitive to eye-spot, and is frequently killed out by an attack that does hardly any damage to surrounding canes. Lahaina, H 109, Yellow Bamboo, and the Tip canes are also sensitive in varying degrees. D 1135, while susceptible, is not so sensitive, and Yellow Caledonia and H 146 are hardly susceptible at all. Neither is Badila. Young cane, as a rule, is more susceptible than the older plants. In one field here a year or so back, there was a mixed planting of H 146 and H 333. An epidemic of eye-spot struck the field, and after it had passed there was no trouble at all in picking out the H 146. The 333 wasn't there.

Non-resistance to eye-spot is an hereditary trait. A count made some years ago showed that 81 seedlings of H 333 were affected, while none of the seedlings of H 109, growing with them, were attacked at all severely.

In comparison with the many factors that affect the cane, the loss caused by eye-spot alone is very small, but even this loss may be largely overcome by planting resistant varieties like Yellow Caledonia, H 146 and D 1135 in places where epidemics are frequent.

(2) *Ring-Spot.*

This disease is caused by the fungus Leptosphaeria Sacchari. It resembles the early stages of the eye-spot disease, but differs from the later stages in that it does not form the characteristic red streaks on the leaves. Eye-spot kills a long strip of the leaf, while ring-spot kills only the small area where the fungus is growing. For this reason the damage is very slight, and the loss caused by the fungus may be disregarded. Our Hawaiian canes do not seem to be very sensitive to this disease, although most of them are susceptible. In the specimens of Badila leaves in the jar here, you can see that the spots are very numerous, yet the cane itself was apparently perfectly healthy, and was making a good stand. Taken all in all, ring-spot may be disregarded as the reason for any great losses in the sugar-producing powers of the cane plant.

(3) *Leaf Freckle.*

This is a rather mysterious disease. It is comparatively rare, and in spite of its looks, practically harmless. It has all the appearance of a fungus disease, but we have as yet been unable to isolate a fungus from the spots, and its cause therefore remains unknown.

(4) *Another Ring-Spot.*

This is a disease which has been found on both Hawaii and Kauai. It resembles the common ring-spot, but the spots are much larger. It is caused by a species of Leptosphaeria as yet undescribed. It is not likely that it will do any appreciable damage to the cane, both from its rarity, and from its relationship to the common ring-spot. It has been found on H 109 and Yellow Caledonia, and also on the "H 400" seedlings.

(5) *Another Ring-Spot.*

This disease is a new one, having been seen first only a couple weeks ago, and of course we cannot say anything about its possibilities for evil. There has not been opportunity to work up the fungus fully, but it appears to be a Leptosphaeria, similar to the one which causes the ring-spot disease. In appearance the disease resembles ring-spot somewhat, only on a larger scale. We cannot say anything yet about resistant varieties, beyond the statement that it has been found attacking both Badila and H 109 cane.

(6) *Pahala Blight.*

This disease does not properly belong in this list, but is here introduced because it is a rather conspicuous leaf disorder. It is characterized by distinct yellow or white stripes in the leaf, as can be seen from the color plate. It is

probably due to an adverse soil condition of some sort, although we are ignorant of just what this condition is. This disease was formerly ascribed to a parasitic fungus, but it has been shown since that the fungus is simply a saprophyte, living on the dead tissue of the leaf. The disease appears in winter, tending to disappear with the advent of warm weather. It attacks all varieties, and may be caused by soil conditions due to the volcano. It occurs in certain fields of one plantation.

(7) *Yellow Stripe.*

This is another leaf disorder that does not belong in this list, but is included because it is so common in the Islands. The cause is not known. The disease is characterized by a light green or yellowish mottling of the leaves, and in some varieties, notably Kokea, and to a lesser extent Lahaina, by a reddish streaking of the sticks. The losses caused by this disease are very great, although just how great is very difficult to determine. In Porto Rico, where the disease has only recently been recognized, the planters claim that unless a cure is found it will wipe out the cane industry of the island. In Hawaii the disease is not so virulent, but in experiments conducted here some years ago the loss in certain of the H varieties ran as high as 46½%. In one case, in Tip canes on homesteads on Hawaii, the loss in cane was estimated at 50%. This is, of course, pretty well above the average, but it tends to indicate that the disease is one that we cannot afford to neglect. In this case again we meet the question of susceptible and sensitive varieties. Nearly all our canes are susceptible. The Tip canes are very sensitive, while Striped Mexican is resistant. D 1135 comes about as near to being immune as any of them. H 109, while susceptible, is not very sensitive, according to the results of the experiments I just mentioned. Lahaina is both susceptible and sensitive. Yellow Caledonia and H 146 are both fairly resistant. The cure for this disease, or rather the method of overcoming it, lies in the selection of seed. Seed from Yellow Stripe sticks will almost invariably give rise to Yellow Stripe stools. In addition to this, experiments seem to show that the disease is infectious. While it is true that clean seed will occasionally give rise to diseased canes, a close selection for a few years should go far toward eradicating the disease. As I said before, the cause of the disease is unknown, and hence I cannot say what it is that injures the cane. The chances are, however, that the injury is pretty much mechanical; the mottling characteristic of the disease cuts down the leaf surface available for starch manufacture, and in that way impoverishes the cane.

(8) *Infectious Top-Rot.*

This is a disease which appears sporadically, and generally in a small patch. Its powers, however, are great, and it may kill off considerable cane if not checked in time. It is characterized by a rotting of the spindle and the growing point of the stick, which effectually puts an end to the life of that particular stick. This is accompanied by an odor which, once smelt, is never forgotten. The disease will spread fairly rapidly, and from its ~~action~~, seems to be of bacterial origin. The particular organism causing it has not been isolated. The rotten tops, of course, are full of bacteria of many kinds, and it is probable that one of these, or several working together, will produce the disease. It

does not appear frequently, but when it does, the surest method of eradication is to cut out and burn the affected sticks. This will put a stop to the spread of the disease in that patch, and generally knock it out for the year at least. The disease is easily recognized in the field, the affected canes quickly dying and turning brown. They can easily be seen from a distance. This disease has great potentialities for harm, and in Mauritius, where it is only too well known, it is said to spread through the fields like wild-fire. The thing to do is to cut out and burn any affected sticks, and do it quickly.

Here are two other leaf troubles that look something like the work of parasitic fungi. The spots shown in the drawing are burns caused by nitrate of soda. The other is Tip Wither. If the cane is making a rank growth, and then a drought, or insufficient irrigation, coupled with high winds, comes along, the tips of the leaves will be dried out, giving the effect shown in the small color-plate.

This, I think, pretty well covers the group of the leaf fungi. The next in order, going down the stick, are those attacking the *leaf sheath*.

(1) *Iliau.*

This is an Hawaiian disease. It is our own product, but was reported from Louisiana in 1913. It was probably carried there in seed cane in times past.

The disease is as characteristic as the name is appropriate. The causative fungus, a soil-inhabiting form, attacks the young shoots before the lower leaf-sheaths are out of the ground. It grows into and around these sheaths, cementing them into a hard, firm case. This cementing is so well done that it is impossible to pull the sheaths from an iliaued stick without tearing them off in strips. Beside this, the sheaths are always pinkish brown in color, and the rind, if the shoot has succeeded in making any stick, is a peculiar bluish gray color. The danger from the disease lies in its faculty of cementing the sheaths together in what amounts to a straight-jacket. The young leaves in the spindle cannot force their way through this, and the stick is killed. The iliau fungus works best in cool, damp weather, and epidemics are to be expected in regions which have one or more months of such weather as a yearly occurrence. Occasionally the fungus will kill out the cane over considerable areas, but its usual practice is to take just one or two sticks in a stool, or occasionally an entire stool. It thrives best at the time when the cane is growing slowest, and many cases are known when the cane has been growing just a little too fast for the fungus. In these cases the cane grows away from the parasite, getting its spindle up to safety before the fungus can cement it in. There have been several measures recommended for the control of this disease. One is the careful removal and burning of iliaued shoots. The best one, however, is to give the cane a good start. Early planting, in regions where the disease is prevalent, will give the cane a chance to get its lower leaf sheaths out of the ground before the fungus weather sets in. The fungus can do no harm to the cane unless it can attack the sheaths. A thorough working over of the soil before the next crop is planted, in order to bring the spores to the surface, is also recommended. A very short exposure to the sunlight will kill the spores.

(2) *Red Spot of the Sheath.*

There are several causes of the red spots on the sheaths, one of which is probably a Cercospora, one of the eye-spot group. The damage done by this is so slight, though, that it may easily be disregarded. I mention it here simply for the sake of completeness.

(3) *Sheath-Rot.*

This is a disease discovered within the last couple years. At times it does considerable damage, but as a general rule it doesn't amount to much. The fungus, which has not been identified, attacks the sheaths, working inward until it reaches the spindle, which it proceeds to kill, thus effectually putting the shoot out of commission. This, like Iliau, works best when the cane is growing least, and good, healthy, rapidly-growing cane will soon grow away from it. In this fact lies the best method of overcoming the disease. Proper cultivation and fertilization will do the work.

(4) *Sclerotial Disease.*

This disease is caused by a very peculiar fungus. It is one of a group that cannot be properly classified, because to the best of our knowledge it forms no fruiting bodies. The threads of the mycelium simply knot up into small hard bodies, which serve to tide the fungus over unfavorable conditions. These, however, are simply resting stages, no spores being produced. For this reason the spread of the disease is very slow, and the areas attacked by it are usually small. The fungus is a sheath parasite, working in somewhat the same way as Iliau, by cementing the sheaths together. However, this cementing it not so tight, and the spindle, if not itself attacked, easily grows away from it. Where the spindle is not killed, the stick will make a normal growth, and experiments have shown that an attack by this fungus has no effect on the quality of the juices. The fungus is fairly easy to eradicate, because of the delicate character of the mycelium. A shallow plowing or two, in dry weather, will kill the mycelium. The sclerotia, the hard knots of mycelium formed as resting stages, are more resistant, and will last for some months, but if the mycelium is killed, the fungus will be effectually checked. It is not of any great importance anyway.

(5) *Phyllosticta.*

This is a parasitic fungus that has apparently been in the Islands for many years, but was only noticed about a year ago. It is characterized by small straw-colored spots on the lower part of the sheath, near the point of attachment to the stem. These spots, in some cases, extend downward onto the rind of the internode below. In some cases, notably in one of the seedlings at the Experiment Station, where the fungus was first noticed, the rind will be rather badly attacked. The cane does not seem to be set back any, though, even by bad attacks, and the disease may well be disregarded. It seems to attack all varieties of cane, and is pretty well distributed over Oahu, at least, and has been found on Maui. But in spite of this it is rare, and there does not seem to be any chance of its ever becoming a serious pest.

The next group of fungi to be considered are those attacking the cane stick. These are very few, in Hawaii, and unimportant.

(1) *Red-Rot.*

The first of these is the Red-rot, caused by the fungus Colletotrichum falcatum. It is weakly parasitic, and is what is known as a wound parasite, depending on an artificial opening of some kind to gain entrance to the interior of the stick. For this reason it does most of its damage to cuttings, where the cut ends offer a convenient point of attack. For this reason, also, it is often connected with attacks by borer and leafhopper. It lives on the sweet juice of the cutting, setting up a fermentation that kills the eye, preventing germination. This fungus caused some worry to the planters here a few years back, but we have heard nothing dangerous from it for several years. In case it does become active again, it is easily overcome by dipping the seed in Bordeaux mixture.

(2) *Pineapple Disease.*

Another parasite of the same type is the fungus which causes the so-called pineapple disease. This fungus, known as Theilaviopsis paradoxa, attacks cane cuttings in the same way that the Colletotrichum does, and in the early stages cannot be distinguished from it except by microscopical examination. As the fungus matures, though, it forms dense masses of black spores on the inside of the cutting, which turns the whole interior of the cutting black. This is another disease that has not been heard from lately, and apparently is not doing any great damage. It is present in the Islands, though, because it is a common fungus in the pineapple fields, causing the large straw-colored spots on the pineapple leaves.

(3) *Eye-Spot.*

This fungus, as I said before, is primarily a leaf parasite, but in one case at least has been known to attack the cane sticks. This exception is H 333. I said that this variety was extremely susceptible, and sensitive, to eye-spot—so susceptible that the fungus leaves its natural preserves, the leaf, and goes out into another region, which accounts for the serious results when an epidemic of eye-spot hits a field of H 333. After it passes, the H 333 very frequently isn't there.

(4) *Sereh.*

In this case, to put it mildly, we're up a tree. The sereh disease, as it is known in Java, is one of the worst, if not altogether the worst, cane disease known. It seems to attack nearly all the varieties grown there, and neither the cause nor the cure is known. The symptoms of the disease are well marked. The cane grows just so far, and then stops short, the leaves turn yellow, and the stick dies. This process is accompanied by an abnormal root growth, the dormant roots in the root-bands practically the whole way up the stick starting to grow. The fibro-vascular bundles in the nodes turn red, and the center of the stick becomes pithy. This pith is white and glistening, having a decidedly waxy appearance. The only way of overcoming the disease in Java is to plant what they call grandmother fields in the mountains, getting their seed from these fields to plant in the lowlands. Sereh is strictly a disease of the lowlands.

Sound seed from the uplands will last about three generations, when it, too, contracts the disease and becomes useless. Three generations means three plantings, all crops in Java being plant crops. Ratooning is not practiced. Clean seed must be planted, for the planting of sereh seed always gives rise to sereh cane. A disease has appeared in Hawaii, somewhat similar to this sereh, and which, for want of a better name, we are provisionally referring to as sereh. This disease shows the same stunted sticks, and the same abnormal root growth, but does not show the waxy center and the red bundles characteristic of the Java disease. Neither does seed of this cane give rise to diseased sticks. We have planted sticks pulled up when practically dead, and they have gone ahead and made a normal growth. Seed from diseased canes does the same thing. Hence, we are not in a position to say much about it. It looks like the Java sereh in some ways, and in other ways it does not. Neither does it act like it when diseased seed is planted. We have been working on this disease, but our results have not as yet shown us very much about it, and until we get more information as to the cause of the disease we cannot very well recommend a cure. It attacks both young and mature cane, and has been found on Yellow Caledonia, D 1135 and H 227.

The last part of the plant to be reached is the roots. The diseases affecting the cane roots are few, but, in the nature of the case, important. It is only natural that any disease which will attack and destroy the feeding organs of an important economic plant will be of great economic importance itself.

(1) *Root Disease.*

The first, and least, of these is the root fungus Marasmius Sacchari. This has been referred to as the Root-disease fungus, the stellate-crystal fungus, and other things. It is easily recognized, the fruiting bodies, which appear at the base of the sticks, being small and very delicate toadstools. These are not, however, to be confused with the small toadstools which are found on decaying trash, mud-press and the like after rains. If a Marasmius toadstool is found, the mycelium may be traced as shiny white threads through the tissues of the leaf sheaths and down into the roots. This fungus, while rather spectacular, was formerly credited with doing a lot more damage than it was really responsible for. There is not much to be feared from it if the cane is kept in a healthy, vigorously-growing condition.

It is a facultative parasite, attacking the roots and the underground parts of stems. It once appeared in virulent form. A trench two feet deep was dug around the infested area, and the area was covered with quicklime, and in a month or two furrowed out and replanted. The disease did not reappear.

(2) *Lahaina Disease.*

And last, but not by any means least, we come to the well-known Lahaina disease. In this case, while the disease itself is mysterious, its results are not, by any means. You are all undoubtedly familiar with the appearance of cane affected with this malady, and the samples here will help refresh your memories. This disease, under various names, has been known for many years in the different sugar-growing countries, and its cause is not yet known with absolute certainty. For a long time nothing was known of the disease beyond the

fact that something was killing the roots, with the resultant collapse of the plant. Various factors were discredited with being the cause—different soil conditions, different fungi, some animal parasites, and so on. Now just recently there have been two new theories offered. Mr. Carpenter, of the Federal Experiment Station, believes the disease is due to one of the mycelial fungi, a species of Pythium, which he finds associated with the disease. Dr. Lyon believes it is due to a very low form of fungus, one of the group that are on the border-line between the plants and the animals. They are a very peculiar group, and nearly all are parasitic on plants of one kind or another. Their status in the social scale may be judged when you know that the botanists claim they are plants, while the zoologists claim them as animals. They have some of the characteristics of both, yet not all of the characteristics of either. These plants (we might as well call them that for the sake of the argument) have the power of contracting themselves into round, heavy-walled resting spores or bodies, to tide themselves over unfavorable conditions, and it was the discovery of bodies of this sort in the living root-hairs of diseased cane that gave the clue. The Pythium also forms fruiting bodies that greatly resemble these resting bodies, and as far as they themselves go they might belong to either of these organisms. However, other organisms, or rather objects which appear to be other forms of Dr. Lyon's organism, have been seen, and these have no relation to the Pythium. Both organisms are found in roots of cane suffering from Lahaina disease, and it is possible that either of them, or both together, may cause the disease. These resting spores and the vegetative bodies belonging to them, are found inside the cells of the roots, and in the cases examined are quite sufficient to cause the collapse of the cane plants. We have several experiments under way at the present time, looking toward the control of the disease, but there has not as yet been sufficient time for them to show any results. The control measures advocated at present are the same as in the past—the planting of resistant varieties. We know that Lahaina is both very susceptible and very sensitive. So is H 146. Yellow Caledonia and Striped Mexican also are affected, while H 109 and D 1135 both show a high degree of resistance, as does Badila.

Finally, we might as well mention a few fungi, harmless in themselves, which have at different times been blamed for causing diseases in cane. The first of these are the stinkhorns. These fungi, purely saprophytic, were at one time named as the cause of root-rot. They are common in the cane fields, and frequently appear in lawns where a tree or plant of some kind has been cut down. There they are growing on the dead roots. In the cane fields they live on the decaying trash and other rotting organic matter. They are absolutely harmless to the cane.

The second, the so-called Rind Disease, is caused by a saprophytic fungus that attacks the dead cane sticks. It is characterized by the formation of black pustules on the sticks, which, under very favorable conditions, grow into long black hair-like structures. In the West Indies this fungus is said to attack healthy cane, killing it off, but in Hawaii it attacks only cane which has been killed by some other cause. It may be found on any piece of dead cane which is exposed for a little time. Sometimes, though rarely, it becomes a very weak parasite, attacking cane which, while still alive, is practically dead from some

other cause. As an active parasite, capable of causing losses in our cane fields, it is nil.

The third is the Sooty Mould. This fungus does cause an extremely slight loss in sugar, but its effect is purely mechanical. It is seen where leafhoppers or aphids are especially numerous, and, as Mr. Swezey told you before, its presence is an indication of the presence of these insects before they themselves are seen. These insects secrete a sweet substance known as honey-dew, which covers the leaves of the plant. This substance is sticky, and dirt and dust blowing about is caught and held. The black fungus favors this honey-dew, and grows luxuriantly upon it, thus, together with the dirt, causing the black, sooty appearance of the cane leaves where the insect pests are abundant. The fungus does not attack the leaves at all, but by covering them up it excludes the light, preventing the chlorophyll from functioning, and to a slight extent injuring the cane. The way to prevent the insignificant damage caused by the fungus is to get rid of the leafhoppers and the aphis.

Fourth—*Monilia sitophila*. This is the bright orange colored fungus that is often seen growing on mud-press in the fields, and on the fresh stumps after the cane is cut. It is feeding on the sugar there, but is absolutely unable to attack standing cane. It is not a cane parasite.

As to Hilling.

An interesting comment on Hilling in Java reaches us through Mr. W. v. H. Duker, who supplies us with the translation from the Java-Archief,* which we quote:

In connection with the hilling up, special attention should be given to keep young shoots separate instead of pressing them together; this applies to all cane varieties, and the more sensitive ones, such as G. Z. No. 100, more especially.

This is a very important point that in no case should be overlooked. As a rule the soil of both sides of the row is more or less pressed against the young and pliable cane stool. The consequence is that the upper roots of the shoots have only a very limited space for development on the inside of the cane stool, and only the roots at the periphery can reach their full growth.

When the precaution is already taken with the first hilling up to place a large lump of soil in the center of the cane stool, which prevents any pressing together of the young shoots, the growing stalks will take up an outwardly bent shape. The upper roots then have more space to take up plant food and the leaves become more free, giving the chlorophyl more benefit from the direct sunlight in the formation of starch.

H. P. A.

*1919, Bul. 12, p. 753.

The Mosaic Disease of Sugar Cane and Other Grasses.†

By E. W. BRANDES.*

HISTORY OF THE DISEASE.

The mosaic disease of sugar cane, the presence of which has recently been discovered in Louisiana and other Southern States, is the malady that in epidemic form has occasioned severe losses in parts of Porto Rico during the past four years. There it has been variously called matizado, "mottlings"; rayas amarillas, "yellow stripe"; morida de perro, "dog bite"; la enfermadad de Arecibo, "disease of Arecibo"; la enfermadad nueva, "new disease," etc. The disease was first noticed in Porto Rico about the middle of 1916.

Starting from some point near Arecibo, on the north coast of Porto Rico, it spread rapidly over the cane fields to the west, down the west coast to the south coast, and up into the valleys and hills of the interior throughout these regions. Its progress eastward was slower, but at the present time more than three-fourths of the cane fields of the island are invaded.

During the last 12 months, methods of control have been put into operation which have undoubtedly aided in checking the spread of the disease into new territory. It has appeared sporadically at a few points in the eastern fourth of the island, but the planters, thoroughly aroused and alert, have not permitted it to spread there as it has in the west. It has become the practice to inspect the fields regularly and eradicate diseased individual plants as they appear, thus removing the source of infectious material. This method has been successful where only a small percentage of the plants are infected. In the west, where 75 to 100 per cent of the plants in commercial fields are diseased, this method naturally can not be recommended. The average reduction in output of sugar for 10 mills in the worst infected area has been nearly 40 per cent, notwithstanding an increased acreage in cane, while the average output for 10 mills in the disease-free area shows a slight gain for the same period. These figures are approximate, but they indicate clearly the gravity of the situation.

The disease is not new, but was recognized as an undesirable condition in sugar cane as early as 1890 in Java, where it is called gele strepenziekte, "yellow stripe."[1] Owing to the failure of Dutch investigators to secure infection by artificial inoculation, they did not regard the disease as infectious, but rather as frequently recurring bud variations. This view was undoubtedly due to the fact that it had for years been present, but unnoticed and unrecorded as a specific disease, so that during this long period unconscious selection had eliminated all but the more or less resistant but not immune varieties of cane. Thus, where the disease had become endemic it would be especially injurious only to varieties imported from countries where the disease did not exist. It would be difficult to carry on

† United States Department of Agriculture, Bul. No. 829.

* Pathologist, Sugar-Plant Investigations; formerly Pathologist, Porto Rico Agricultural Experiment Station, Mayaguez, P. R.

1 Wilbrink, G., and Ledeboer, F. Bydrage tot de kennis der gele strepenziekte. Meded. Proefstat. Java-Suikerindus., No. 39, 2, pp. 443-495, 5 pl. (4 col.), 1910.

successful infection experiments where the disease is as prevalent as it is in Java.

Dutch investigators reported the presence of yellow stripe in Egypt in 1909 on cane imported from Java and in the Hawaiian Islands in 1910. In the latter territory nearly all cane regions have become infested, and careful experiments have shown that where all plants in a field are attacked, according to Table 1, it causes a reduction in yield of sugar of 5 to 40 per cent, depending upon the variety of cane.

TABLE 1.—TESTS OF SUGAR CANE, SHOWING VARIETAL RESISTANCE TO THE YELLOW-STRIPE (MOSAIC) DISEASE IN THE HAWAIIAN ISLANDS.[1]

Variety[2]	Condition	Canes		Test of Juice			Requirement per Ton of Sugar		Loss Due to Disease
		No.	Ave. Wt.	Brix Scale	Sucrose	Purity	Wt. of Cane	No. of Canes	
Plant cane (18 months old):			Lbs.	Deg.	Pct.	Pct.	Tons		Pct.
H 227	Striped	60	4.10	18.5	16.7	90.3	7.81	3,810	18.05
	Healthy	212	5.17	18.0	16.2	90.0	8.07	3,122	
H 151	Striped	50	5.73	18.4	16.5	89.7	7.95	2,775	15.20
	Healthy	248	6.57	18.8	16.9	89.9	7 73	2,353	
H 135	Striped	50	5.69	17.3	15.7	90.8	8.29	2,914	15.97
	Healthy	292	6.96	17.2	15.4	89.5	8.52	2,448	
H 90	Striped	57	5.50	18.5	16.6	89.7	7.90	2,873	20.64
	Healthy	244	7.08	18.3	16.3	89.1	8.07	2,280	
H 69	Striped	38	4.50	18.7	16.6	88.8	7.92	3,520	26.09
	Healthy	265	6.12	18.8	16.6	88.0	7.96	2,606	
H 38	Striped	16	5.12	19.3	17.7	91.7	7.33	2,863	5.83
	Healthy	296	5.60	18.8	17.2	91.5	7.55	2,696	
H 27	Striped	39	8.03	19.1	17.1	89.5	7.67	1,910	10.16
	Healthy	172	9.16	18.7	16.7	89.3	7.86	1,716	
H 2	Striped	16	4.00	18.8	16.9	89.9	7.73	3,865	34.9
	Healthy	174	6.39	18.5	16.4	88.6	8.04	2,517	
H 197	Striped	34	6.34	19.0	17.1	90.0	7.64	2,410	6.06
	Healthy	154	6.90	18.6	16.8	89.4	7.81	2,264	
H 276	Striped	32	6.01	18.1	15.7	86.7	8.49	2,825	14.46
	Healthy	196	6.96	18.2	15.8	86.8	8.41	2,417	
H 291	Striped	79	4.05	20.0	18.1	90.5	7.21	3,561	19.7
	Healthy	185	5.10	19.8	17.9	90.4	7.29	2,859	
H 338	Striped	20	4.00	19.8	17.6	88.8	7.47	3,735	46.45
	Healthy	191	5.50	20.2	18.0	89.1	7.31	2,659	
H 339	Striped	15	4.03	16.7	14.5	86.8	9.17	4,551	27.76
	Healthy	126	5.25	17.7	15.4	87.0	8.68	3,288	
H 355	Striped	219	5.25	18.8	15.5	82.4	8.81	3,356	13.72
	Healthy	70	6.08	19.2	15.7	81.8	8.73	2,895	
First ratooned cane (11 months old):									
H 363	Striped	75	4.73	19.3	17.2	89.1	7.65	3,235	8.04
	Healthy	66	5.13	19.2	17.2	89.6	7.63	2,975	
H 197	Striped	58	2.80	19.9	18.2	91.5	7.18	5,090	24.63
	Healthy	310	3.60	20.3	18.7	92.1	6.91	3,840	
H 109	Striped	109	3.99	19.5	17.9	91.8	7.22	3,619	0.5
	Healthy	286	3.96	19.9	18.2	91.5	7.13	3,601	
H 69	Striped	84	3.50	19.0	16.7	87.9	7.91	4,520	14.76
	Healthy	213	4.08	19.1	16.8	88.0	7.86	3,858	
H 27	Striped	243	4.89	18.5	16.4	88.6	8.04	3,288	29.93
	Healthy	34	6.51	19.6	17.5	89.3	7.50	2,804	
Yellow Caledonia	Striped	16	2.56	19.7	17.8	90.4	7.33	5,727	26.1
	Healthy	372	3.66	19.1	17.0	89.0	7.74	4,229	
H 22	Striped	260	3.09	17.6	15.2	86.4	8.77	5,676	30.9
	Healthy	68	4.37	17.8	15.5	87.1	8.57	3,698	
H 20	Striped	24	4.10	19.3	17.3	89.6	7.08	3,454	11.97
	Healthy	345	4.73	19.9	18.1	91.0	7.19	3,040	

[1] Lyon, H. L. Losses due to yellow stripe disease. In Hawaiian Planters' Record, v. 6, No. 5, pp. 258-263, 1912. (Permission to use the data in this table was obtained from the editor of the Hawaiian Planters' Record.)

[2] H = Hawaii seedling.

Table 1 indicates clearly that the loss is due almost entirely to reduced tonnage. Diseased canes are uniformly much lighter than healthy canes of the same variety.

During the early part of the present year the mosaic disease was discovered by the writer at three different points in Cuba, apparently as the result of separate importations. At Cienfuegos it has been present for nearly 20 years, but as a result of their discarding diseased plants in the seedling and propagating fields because of their unthrifty appearance, and perhaps partly owing to the fact that a proper agent of transmission was not present or at least not abundant in this region, it has spread very little. At Santiago de las Vegas it was found on plants recently imported from Louisiana and from Tucuman, Argentina. The latter plants had come originally from Java. The disease had spread from these plants to an adjoining field of the native Crystalina cane. In view of this demonstration of its ability to spread at Santiago, it is very fortunate that the diseased plants were early observed and destroyed. A slight infection has been found at Mercedes, also as the result of a recent importation.

Infected cuttings have been received in both Porto Rico and Cuba from Tucuman, Argentina, but to what extent the disease is prevalent in Argentina has not been learned.

Last year the mosaic disease was found in abundance at La Romana and the city of Santo Domingo, Santo Domingo, and less plentifully at Samana, La Vega, Monte Cristi, and Bonao.[3] Lastly it was discovered at St. Croix, Virgin Islands, on cane imported from Porto Rico.[3]

Distribution in the United States.[4]

The presence of the mosaic disease in the United States was first suspected when an agent of the Office of Sugar-Plant Investigations of the United States Department of Agriculture discovered young diseased cane in Porto Rico from seed cane imported from Louisiana. The plants were so young at the time that secondary infection seemed improbable, and it was assumed that the seed pieces were diseased when shipped from Louisiana. Accordingly another agent of the same office visited Louisiana and on July 7, 1919, confirmed the presence of mosaic there. The State authorities were apprised of this important disclosure, and the Government agent made a hurried reconnoissance of the Gulf States, which revealed the fact that the disease was already quite widely distributed there.

On account of the infectious nature of the malady and the fact that it has caused severe losses in other cane countries, a complete survey of the Southern States was immediately instituted to determine the location of all infested areas and, if possible, to trace the original importation of the disease and the course of its subsequent spread. Infested areas have been well delimited. The disease has been found by inspectors of the United States Department of Agriculture in Louisiana, Florida, Georgia, Alabama, and Mississippi (Fig. 1). It is most abundant in Louisiana, as would be expected. There the river district is already badly infested. As far north as Angola, in West Feliciana Parish, several fields

[3] Stevenson, John A. The mottling disease of sugar cane. In Jour. Dept. Agr. and Labor, Porto Rico (in press).

[4] Thanks are due to Mr. W. G. Taggart, vice director of the University of Louisiana Sugar Cane Experiment Station, and to Dr. C. W. Edgerton, pathologist, Louisiana Experiment Station, for courtesies extended to the writer and suggestions facilitating the survey in Louisiana.

in a large plantation were found in which 75 per cent or more of the plants had the mosaic disease. From this point south to Donaldsonville, however, the amount of infection is not heavy. Many plantations are entirely free from mosaic, so far as can be determined by inspection. From Donaldsonville to New Orleans an increasing amount of infection was recorded by the inspectors. Between Lutcher and Reserve, about 75 per cent of the plants in every plantation were infected. This is by far the most heavily infested large area in the United States. From this region to New Orleans and from New Orleans to the lower extremity of the river district the amount of infection ranges from 4 to 30 per cent. Just a few fields were visited where no mosaic was found.

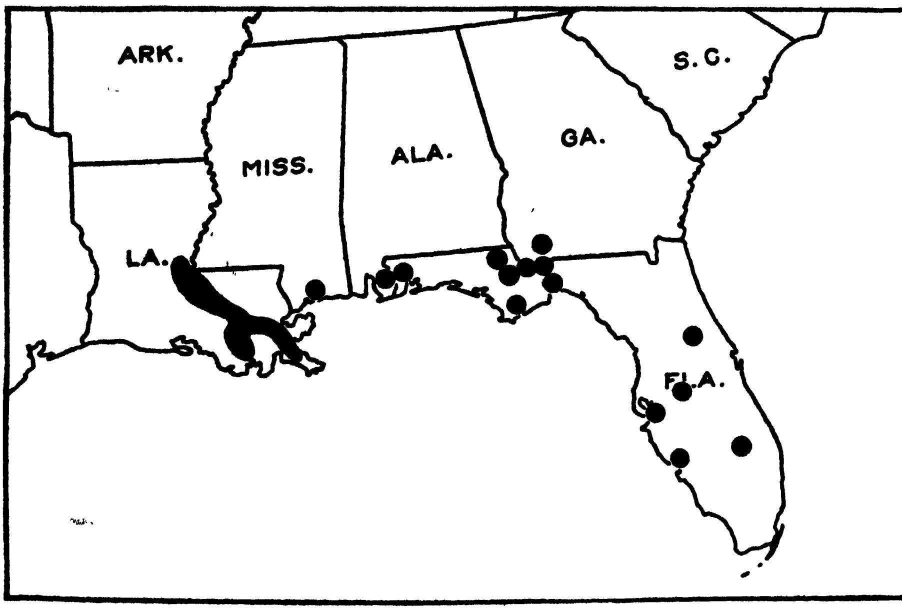


Fig. 1. Map showing the location of diseased areas of sugar cane in the United States.

In the Bayou Lafourche district mosaic was found in only about one out of four fields visited, and where present amounted to only 1 to 8 per cent of the plants. In the Bayou Teche district no mosaic was found on plantation cane, although nearly 500 fields were carefully inspected. A few cases were found in this region on cane recently distributed by the State Sugar Experiment Station. The immediate destruction of these few sources of infection is a matter of great importance. No mosaic whatever was found west of Bayou Teche or in Avoyelles and Rapides Parishes to the north. Thus, a very considerable part of the sugar-cane lands of Louisiana is still free from the disease, and every effort should be made to keep it free.

In Georgia the worst infested region is in the vicinity of Cairo, Grady County. There the proportion of infection ranges from less than 1 to 75 per cent or more in fields where the disease is present, but only about one-fourth of the cane fields in this county harbor the infection at all. The affected area is quite sharply delimited, all of the disease being confined at present to farms located on the highways leading out from Cairo. The cane fields in Georgia consist usually of a few acres grown for sirup making. It is quite possible that

by prompt and energetic action this community could free itself from the mosaic disease in short order.

Cane fields are distributed over practically the whole State of Florida, but the crop is grown largely for sirup for home use and the cane patches are even smaller than those in Georgia. Mosaic has been widely scattered over the State by the distribution of cuttings from experimental plats grown for the purpose of testing varieties. There are only two points, however, where the disease has spread so as to include any considerable area, namely, the vicinities of Marianna and Bristol. Other points in Florida where mosaic has been found include Apalachicola, Tallahassee, Punta Gorda, Palmetto, De Land, Winterhaven, Chattahoochee, Muscogee, and Canal Point. These are all purely local infections, and in some cases the disease has not yet spread more than a few rods from the original plantings shipped in from other States. An eradication campaign would be entirely practicable in Florida.

Mosaic has been discovered at only one point, Biloxi, in Mississippi. From the farm on which it first appeared it spread to one other farm in the vicinity.

In Alabama similarly, it was found only on one place, near Muscogee, Fla. It was confined to the farm where it first appeared.

Final reports on the results of the inspection in Texas must be deferred, since the survey is still under way in that State.

The survey has also been very illuminating concerning the probable time of introduction of the disease into this country and the method of its subsequent spread here. Since 1913 a prohibitory regulation has been placed upon the introduction of sugar cane into the continental United States, and it is probable that no cane has been introduced since that time. Prior to 1913 varieties of sugar cane were imported many times by private individuals and by various Government agencies. The Sugar Experiment Station of the Louisiana State University, at Audubon Park, has been particularly active in importing new varieties, with the idea of securing some higher in sugar content and yield than those already grown here. Whether the mosaic was introduced by the experiment station or by private individuals, no particular blame attaches to those who are responsible for the importation of this obscure disease. There is no known method by which the presence of the disease in cuttings can be positively established. It is merely pointed out that such an importation would be practically impossible with the present quarantine against sugar cane. Concerning the probable time of the importation that was responsible for the present wide distribution of mosaic in America, the survey has brought out the fact that the distribution of cuttings by the Louisiana Sugar Experiment Station in 1914 and prior to that time has not resulted in establishing the disease at the points where such cane was received. Since 1914, however, every point receiving seed from the station has become the center of a larger or smaller infected area. The inference, of course, is that while the disease may have been present at the station for a few years prior to 1914, it had not become so widespread that every seed shipment from there contained some infected cuttings. At the present time, about 97 per cent of the cane plants at the station have the mosaic disease. It is probable that private individuals have imported cane with this disease, but

such cane is not likely to be widely distributed, and its spread, therefore, must depend upon natural agencies, a much slower process.

Without exception, every infested area in Georgia and Florida can be directly traced to distributions of seed cane from the Sirup Field Station at Cairo, Ga., since 1916, and the infection at this station dates from the importation of a number of varieties from Audubon Park in 1915. In nearly every instance where diseased cuttings have been received from Cairo, it has resulted in secondary infection of the surrounding native cane.

The above is the brief and much condensed compendium of a large amount of data collected during July, August, and September, 1919. It has made possible the recommendation of plans of attack upon the mosaic disease, which vary slightly in the different cane regions of the country, but all of which, if strictly adhered to by every cane planter, will bring the disease under control. Its capacity for rapid spread, as demonstrated in Georgia and Florida, means that a lapse of one year will result in immeasurably complicating the problem of ultimate eradication.

Losses in the United States.

Since the mosaic disease had been unrecognized in this country until the writer announced its presence in July of this year, no extensive data have been accumulated to determine whether the losses caused by it in the United States are comparable with those sustained in Porto Rico. A few figures (Table 2) have been obtained in Louisiana, however, which indicate that we may expect a decrease in yield almost equal to that in Porto Rico if the disease is permitted to become as widespread here as it is in that country. Losses here are held in check somewhat on account of frequent replanting. It has been noticed that where infected sugar cane is allowed to ratoon over a long period of years that losses due to the mosaic are more severe each successive year. The figures in Table 2 were obtained by cutting all of the cane in approximately square patches of about one-tenth to one-fifth of an acre selected in commercial fields and in the fields at the Sugar Experiment Station, Audubon Park, La. The stalks cut from such patches were then sorted into two classes, diseased and healthy, and the average weight of stalks in each class was determined. The patches were not selected at random, but an attempt was made to find areas where the mosaic was doing a maximum amount of damage and at the same time a sufficient number of healthy plants were present in the patches, growing under identical conditions, in order to make a fair comparison possible. Since, if no attempt is made to control the disease in these fields, we may expect ultimately to find an infection of 100 per cent, the losses will then be equivalent to the figures found in column 5 of Table 2.

TABLE 2.—TESTS OF SUGAR CANE IN LOUISIANA, SHOWING THE EXTENT OF LOSSES IN DIFFERENT VARIETIES.

Variety	Number of Stalks		Average Weight of Stalks		Reduction in Weight of Diseased Stalks	Diseased Stalks in Field	Loss in Tonnage
	Healthy	Diseased	Healthy	Diseased			
			Pounds	Pounds	Pct.	Pct.	Pct.
Louisiana Purple	330	160	1.13	0.7	38	32	12.16
Louisiana Striped	268	100	1.507	1.22	19	27	5.13
D 74	204	108	1.27	1.03	18	34	6.12
D 95	348	136	1.65	1.16	29	28	8.12
L 511	373	310	0.874	0.787	10	45	4.5

PRIMARY SYMPTOMS.

Upon walking between the rows of cane in an affected field, more or less plants will be seen that are conspicuous on account of a general pallor of the leaves. This may be discernible for many rods. Closer examination of such plants reveals that the pallor is due to irregular light-colored streaks or spots on the leaves. The affected leaf areas, in so far as color is concerned, are of two distinct types. The most common type presents merely a "washed-out" appearance. It is, in fact, merely a tint of the normal color, in which the blue and yellow are present in the same proportions but diluted. In the second type, the yellow is predominant, and the affected areas have a decidedly yellowish green appearance. The normal and affected areas are sharply demarked. In other words, there is no gradual merging of one color into the other. There is a great diversity of patterns in the different varieties, due to the variation in the amount, size, and shape of the light-colored areas, but the arrangement is so constant in any particular kind of cane that the character could be used as an aid in determining varieties.

Among the cane varieties commonly grown in Louisiana and other Southern States, some rather constant differences occur in the expression of the mosaic disease. In L 511 it will be noticed that streaks are rather scant in newly-invaded leaves and on account of their light color make a great contrast with the normal areas. They are bluntly pointed and range from one-sixteenth to three-sixteenths of an inch wide and from one-fourth of an inch to 3 or 4 inches long (Pl. I, Fig. 4). Later, the light areas or streaks are more numerous and in most cases tend to become confluent in well-defined bands of light tissue extending across the leaf at right angles to the midrib and alternating with bands where the light streaks remain isolated. These bands are from 1½ to 2 inches long. The above condition is typical of the disease as it appears in L 511, but does not invariably occur.

In D 74 the streaks are not usually isolated, even at first, so that very quickly the coalesced light areas are predominant and the normal areas appear as irregular, elongated islands 1 thirty-second to three-eighths of an inch wide and of varying length, from one-fourth of an inch to several inches, as shown in Plate I, Fig. 5.

Affected areas are light green at first, but the tendency for the whole leaf to become opaque yellow is pronounced.

In purple cane the light areas are elongated and isolated at first, but later they predominate and coalesce and the normal green shows as irregular elongated islands, as illustrated in Plate I, Fig. 5. The islands are not of uniform width or length.

In the youngest leaves of Ribbon cane, the light areas are in the shape of attenuated streaks, usually about one-eighth of an inch wide and one-half of an inch to 1½ inches long, but the size varies greatly, some streaks being very minute, and others, by running together at the ends, form continuous stripes 6 inches or more in length. In general, the streaks are isolated from one another and uniformly distributed on the leaf blade as in Plate I, Fig. 4. The amount of normal-colored tissue greatly exceeds the light tissue at this time. Exceptionally, the light streaks may be confluent from the first, and this is more frequently seen near the midrib, leaving the margin normal in color or with a few scattered pale streaks. In slightly older leaves, by growth and confluence of the light-colored areas the latter becomes predominant and the whole leaf becomes pallid or even yellow in its general appearance. The dark-green or normal areas are now very scant, and they appear as elongated streaks in the pale green, just the reverse of the condition in young leaves, except that the dark-green streaks are less regular in outline. The individual streaks vary considerably in width and direction throughout their extent, streaks perhaps three-eighths of an inch wide at one end becoming constricted to 1 thirty-second of an inch, then alternately widening and narrowing or becoming oblique with the midrib, with no apparent forces limiting their extent or direction except that in general they are elongated in the direction of the parallel veins of the leaf.

In D 95 the light areas are predominant from the start (Pl. I, Fig. 5).

In L 219 the light streaks are isolated near the base of the leaf, but become confluent toward the tip.

In L 226 the streaks are isolated and even in older leaves remain so.

L 231 is very severely injured. The leaves are usually quite yellow, as shown in Plate I, Fig. 6. Practically the entire surface is light from the beginning. There are exceptions, however. The amount of injury in this variety is variable.

L 253 is quite tolerant. The lighter areas predominate, but are not yellowish. All plants seen were dark green and vigorous.

Secondary Symptoms.

Field observations covering a number of years indicate that the deleterious effects of the mosaic disease are cumulative. The streaking and spotting of the leaves discussed above are the only noticeable signs in newly-infected plants. The disease is never fatal during the first year and, in fact, it rarely terminates in death even in diseased plants that have been allowed to ratoon for years. Usually, however, more serious effects are seen in first ratoons of cane which became infected the previous year or in plant cane originating from diseased cuttings. At this time another quite distinct leaf symptom appears. It consists of small white opaque spots and streaks in the light-colored areas. These streaks are smaller than the light areas previously mentioned, and differ from them in having no

pigment whatever. They range from mere points to elongated irregular streaks several inches in length. The white streaks may become confluent to a limited extent. They are for the most part restricted to the light-green areas of affected leaves, but do not correspond to them in outline and typically remain more or less isolated from one another. The white opaque tissue has a dried-out appearance and seems to be quite functionless. It remains firm, however, and does not become brown or rot out. The amount of total leaf area occupied by this type of tissue rarely exceeds 20 to 30 per cent of the whole.

At about the same time, or during the next year, a still more injurious sign of mosaic appears, namely, the striping or cankering of the stalk. This is much more marked in some varieties than in others. Ordinarily, it does not become noticeable until the cane is quite well developed. By tearing away the enveloping leaf bases, cankers can sometimes be found in the incipient stage. They appear as discolored or water-soaked patches or longitudinal streaks on the internodes. In severe cases these areas become sunken and the internodes are spindle-shaped and attenuated. Longitudinal cracks may appear, resulting in the drying out of the cane. There is a tendency toward shortening of the joints and premature development of roots and shoots at the nodes of standing cane. Figure 2 shows such a condition in Yellow Caledonia cane. The photograph reproduced here was taken at Arecibo, Porto Rico, in 1919, and the probabilities are that the plant had been infected for at least five years. These identical cuttings and similar ones were brought to Washington and planted in a quarantine greenhouse. Most of them grew, but at the present time, five months after planting, they are scarcely 1 foot tall. The opaque white streaking covers practically all of the leaf area. This is the most excessive injury ever observed by the writer. Most varieties of cane do not go to pieces like this, but rather the injury to stalks consists merely of retarded development. Among the well-known varieties, however, all gradations in the extent of injury between these two extremes are to be found.

When a large proportion of the plants in a field are infested, the aspect in general resembles the effect of a severe drought. The foliage of the entire field is yellowish, and the plants are more or less noticeably stunted. Where a row of some immune variety is planted in or near a badly infested field, the contrast in color is exceedingly conspicuous and the dwarfed habit of infected plants is more noticeable. It is possible to recognize such fields from a distance of half a mile or more on account of their sickly, dry appearance.

Injuries Resembling Mosaic.

Many types of injury are commonly found on cane leaves that might be confused with this malady by one not familiar with it. The condition termed chlorosis, which is due for the most part to soil conditions, expresses itself in many ways, some of which closely simulate the mosaic disease. The affected areas are white opaque or yellow, and the most familiar form is a regular striping of the leaves longitudinally. The stripes usually extend the entire length of the leaves and may be about one-eighth of an inch wide and numerous, with normal green stripes of equal width spaced between them, or the chlorotic areas may be quite wide. Occasionally, the entire leaf is pure white. Less frequently the areas are in the form of large spots or blotches, extending inward

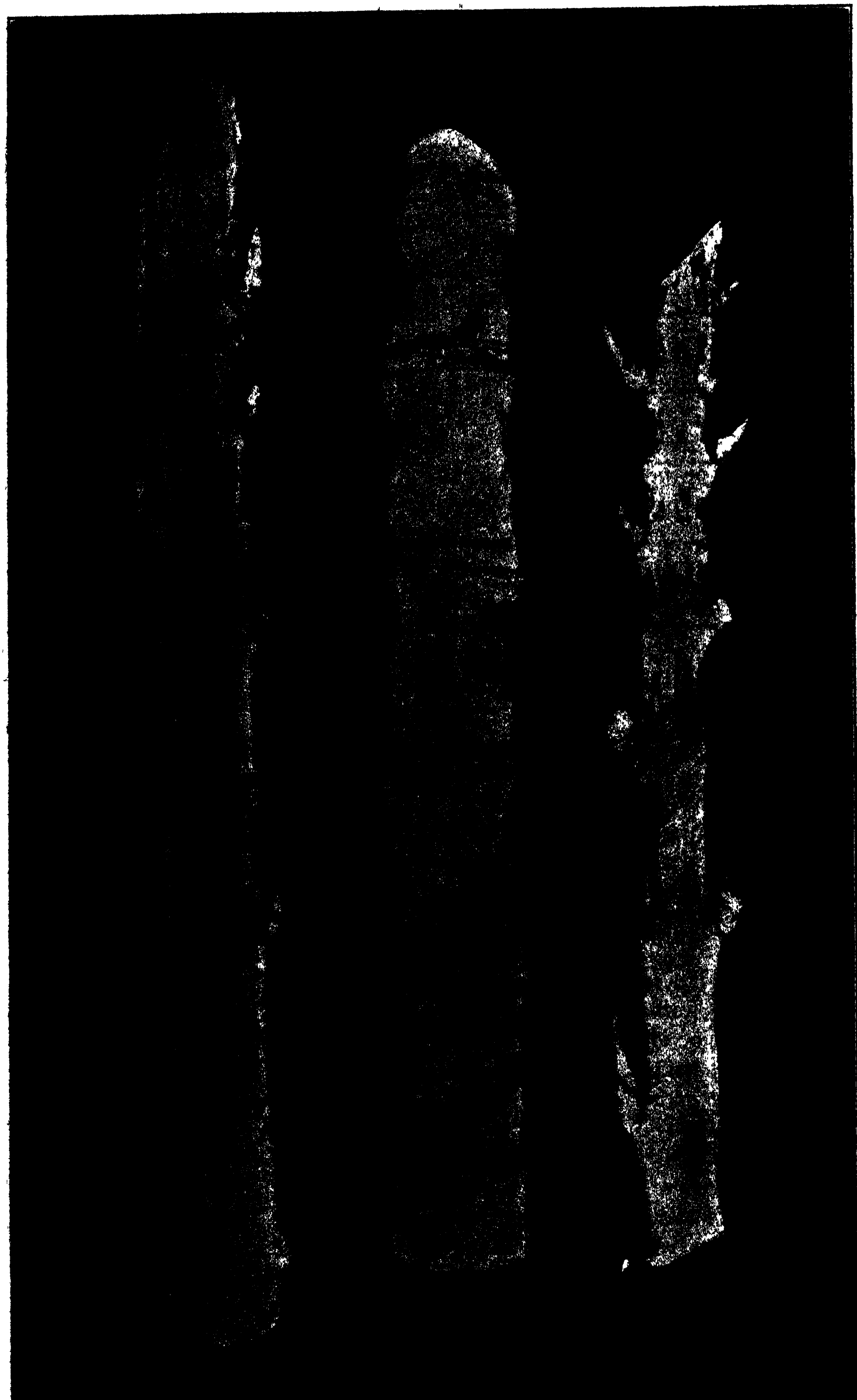


Fig. 2. Canker stage in Yellow Caledonia sugar cane; healthy cane of the same variety in center.

from the margins of leaves or situated at the center of the blades anywhere from base to tip. Another type, which is rare, consists of a very fine irregular white mottling of the leaves, which, however, is in local patches and does not involve the whole leaf, as is invariably the case with the mosaic disease. Many fungi cause spotting of the leaves of cane, but these can easily be distinguished, as the spots usually turn brown and the leaf tissue dies, which does not occur in the cane mosaic. Since a pale-green halo is sometimes present surrounding these small spots, they have the appearance of mosaic from a distance, especially when quite numerous, but a close examination always reveals quite distinct differences. Many insects, especially those which feed by puncturing the leaf epidermis and sucking the sap from the layers of cells below, cause a very fine mottling of the leaves when the punctures are present in enormous numbers. Ordinarily, the punctures are scattered and can lead to no confusion. This type of injury can also be determined by close inspection, since the minute pale area surrounding each individual puncture is almost exactly circular and has no tendency to elongation in the direction of the long axis of the leaf, such as is almost invariably the case in true mosaic. Drought, lack of proper nutrients in the soil, excessive rainfall, and poor tilth, or combinations of these, sometimes result in a general pallor or yellowing of the leaves, but this color is always uniform and can lead to no confusion.

Varietal Susceptibility.

VARIETIES ATTACKED.

More than a thousand varieties of cane have been determined to be susceptible to the mosaic disease. Most of these are the progeny of seedling canes that exist in small variety-test rows or patches at the various sugar-cane experiment stations, but the list includes also practically all of the commercially esteemed sorts grown for the mills on a plantation scale.

So far as can be learned, none of the varieties grown in Java is truly immune, but a high degree of resistance or tolerance of the disease has been observed in the favorite Java seedling canes grown in Porto Rico, a probable explanation of which has already been given. Only Java 56, 100, 228, and 234 have been seen by the writer in Porto Rico, but all of these, though 100 per cent of the individuals were affected, made a thrifty growth and produced apparently normal stalks. The leaves are not noticeably yellowed, but, on the contrary, appear to be of uniform dark-green color when viewed from a distance. Close inspection, however, shows the characteristic streaks, but the diseased areas are very little lighter than the normal areas. Probably the damage done to an individual plant is slight, but the aggregate damage to all of the individuals in a field is a measurable quantity and has been shown to be quite considerable in Java. In the different varieties all degrees of tolerance are exhibited, ranging from the highly resistant Java canes down to the soft white Otaheite or Bourbon cane, which is so severely injured that the cane is hardly worth milling. In addition to the conditions which might be termed varietal tolerance of the disease, some varieties exhibit decided and rather constant differences in the percentage of individuals that become affected under the same conditions. This is brought out in variety-row tests where the same varieties have been planted at several

points in the same field. Under these conditions it has been found that some varieties will show a 100 per cent infection of the individuals in all of the rows, while in others perhaps only 60 per cent of the plants will be diseased in each of the separated rows or plats. It seems reasonable to suppose that all varieties were equally exposed to the contagion in such situations. This fact indicates a possibility of resistant strains among the individuals of a variety.

The Rayada or Striped cane and the Crystalina or White Transparent, the two favorite varieties in Porto Rico, are severely injured. Yellow Caledonia is grown on a large scale in some localities, and plants of this variety killed by the mosaic disease have been observed. This is quite unusual, since attacked plants of most varieties become badly stunted but do not die. All seedling canes from Demerara and Barbados grown in Porto Rico are attacked. Seedlings of the Insular and Federal agricultural experiment stations likewise are all affected, as are the seedlings originated at Centrals Guanica and Fajardo. Among the varieties planted commercially, to a limited extent the Bambu, Cavengerie, Morada, and, in fact, all the broad-leaved canes have proved to be susceptible.

In Cuba all varieties that are exposed seem to become infected, but since the disease has not become rampant nor spread over any considerable area, no opportunity to observe the reaction of all the varieties grown there is to be had. Practically all of the seedlings originated in the Harvard Experiment Station near Cienfuegos were affected, as well as the imported Java 228, L 511, and the native Crystalina at Santiago de las Vegas.

Practically all varieties are attacked in the Hawaiian Islands, and extensive damage is done.

The common varieties in Louisiana have proved susceptible to mosaic disease. Louisiana Purple, Louisiana Striped, D 74, D 95, L 511, L 218, L 219, L 226, L 231, L 253, and hundreds of seedlings being tested at the Louisiana Sugar Experiment Station all fall prey to the ravages of this disease.

IMMUNE VARIETIES.

Fortunately a few varieties of sugar cane have been discovered which appear to be entirely immune. Most of them are of the slender North India type, generally known as Japanese canes. The Kavangire, a variety which, because of its prolific stooling, yields a very large tonnage and is much esteemed in Argentina for making sugar, has never been observed to be diseased, although it has been exposed to infection for four years in the worst infested regions of Porto Rico.[1] It is a rather long season cane, however, and for this reason is probably not suited to Louisiana conditions. Another Japanese cane, Cayana 10, which is becoming prominent in the sirup sections of Georgia and Florida, is also immune. This variety has already met with considerable favor on the part of cane growers in Georgia. All the other Japanese varieties observed, including many imported by the Office of Foreign Seed and Plant Introduction of the Bureau of Plant Industry, have been found to be uniformly free from this disease.

[1] Townsend, C. O. An immune variety of cane. (Abstract of an article by F. S. Earle.) In Science, n. s., v. 49, no. 1272, pp. 470-472. 1919.

Among the broad-leaved thicker stalked varieties several kinds have been found that appear to be immune, but our evidence of their immunity is not so complete as is the case with the Japanese varieties. Louisiana seedlings 1646, 1606, 1674, and 1797, growing in the variety test plats at Audubon Park, New Orleans, this year appeared to be immune. No individuals of these varieties were diseased, although they were surrounded by other varieties, the individuals of which averaged 97 per cent diseased.

Other Hosts.

A number of other grass plants are known to be subject to the mosaic disease, but apparently they are attacked with difficulty and only under conditions favorable to the disease. Among these hosts are corn, sorghum, rice, millet, crab-grass, foxtail, and Panicum. Probably the list of susceptible plants is much larger, but up to the present time opportunity for testing others has not been had. In the case of corn, rice, and millet, we have no experimental proof that the diseases are the same, but must depend upon field observations. If not the same, the disease must be very similar, since the leaf symptoms are identical. The characteristic streaked and spotted appearance of the leaves is present in all attacked plants.

With regard to sorghum, crab-grass, foxtail, and Panicum, our evidence is conclusive and proves that the infectious material or virus is the same for all of these plants. Sorghum seed of the Early Amber, Sugar Drip, and Japanese Ribbon varieties was sown in a bed at the quarantine greenhouse at Washington, where diseased plants of 17 different varieties of sugar cane were growing. When the sorghum plants were about half grown, practically all of them began to produce mottled leaves and continued to do so until they went to seed.

The seed was saved from these sorghum plants to determine whether the disease is transmitted to the next generation in the true seed.[2] The leaf symptoms in these greenhouse plants were exactly like the symptoms on sugar-cane leaves. Plants arising from the same batch of seed used in the greenhouse experiment cited above but planted elsewhere and not exposed to the disease did not show the phenomenon, but produced healthy leaves of uniform color. The crab-grass, foxtail, and Panicum came up as volunteer plants in the quarantine greenhouse. Scores of stools of these weeds were allowed to mature for observation and identification. Every plant became infected and exhibited the typical leaf symptoms. Some half dozen other species of wild grasses were present in the greenhouse, but they were not attacked. All of the wild grasses were abundant outside of the greenhouse, but in spite of an assiduous search in the vicinity not a single infected plant could be found. The conclusion to be drawn from these observations is obvious. We are not dealing with similar mosaic diseases of these various graminicolous hosts, the viruses of which are specific for each host, but with one and the same disease.

The existence of other host plants, especially the common wild grasses, would appear to be one of the most alarming of the recent developments in the problem. It is needless to say that the control of the disease would be immeas-

[2] This seed was planted in flats. At the present time, three weeks after germination, no sign of the mosaic has appeared.

urably complicated if it were to become prevalent on such omnipresent weeds. Fortunately, however, our observations appear to indicate that the grasses other than cane become infected only under conditions favorable to the disease and in the near vicinity of infected sugar-cane plants. Infected corn, for instance, has been seen by the writer only in Porto Rico, where it was growing between the rows of diseased cane stubble. Infected rice plants were observed there only once, growing just across a narrow dirt road from a badly attacked cane field. At Audubon Park, La., attacked sorghum was seen in the similar situation, the most remote plants being only about 3 rods from the cane, and the percentage of attacked plants decreased in an inverse ratio to the distance from the cane. The same was true of crab-grass, which was abundant in the sorghum field. These observations are encouraging and tend to offset the disconcerting facts discussed above.

Nature of the Disease.

INFECTION PHENOMENA.

Sugar-cane mosaic is an infectious chlorosis, similar in many respects to the mosaic diseases of tobacco, cucumber, bean, tomato, and potato. Evidence of its infectious nature exists in hundreds of field observations and in the infection of experimental plants under controlled conditions. The well-defined epidemic in Porto Rico, in which it has been established that the disease started in a small local area and gradually spread from this focus of infection, diseased plants being confined within the limits of the ever-increasing infested territory and not appearing sporadically at remote points, is convincing. It leads to the inevitable conclusion that some virus or inoculum is responsible for the appearance of new cases and that the only source of inoculum is some plant previously infected with the disease. No other explanation accounts satisfactorily for the observed facts. Climatic conditions were at first suggested, but the epidemic has lasted already for a period of years, during which rainfall, temperature, sunshine, and the other factors that go to make up climate have been normal. The wearing out of soils was regarded as a possible cause, but during the steady progress of the disease it gradually encroached upon every conceivable type of soil, including the richest and most productive in the island. Strong support was given to the idea that it was a case of deterioration or the "running out" of varieties, but when it became evident that all varieties present in the invaded district were affected, this idea was abandoned. For the same reason the hypothesis that it is a case of bud variations, or "sports," seems highly improbable, and when the regular progress of the epidemic is borne in mind, radiating outward as it does from a common starting point, there is seen to be nothing to substantiate this claim.

Only a few specific observations of infection may be cited in the limited space available. In October, 1918, healthy seed of about 80 varieties was brought into the infested area from disease-free regions in order to determine whether any natural immunity existed among the varieties present in Porto Rico. This seed was planted at the Santa Rita estate, near Yauco. When the seed germinated, the young plants were seen to be healthy and normal, but within six weeks to two months practically every plant of all varieties with one excep-

tion (the Japanese Kavangire) showed the unmistakable symptoms of mosaic. This was a clear case of secondary infection from the fields of diseased cane surrounding the test plat.

At Santiago de las Vegas, Cuba, about 200 seed pieces of Java 228 cane imported from Tucuman, Argentina, were planted in two rows, and two rows of the native Crystalina cane were planted beside them. The Java cane was 100 per cent infected when it came up, the cuttings having come from diseased parent plants. When this planting was examined in June, 1919, 75 per cent of the Crystalina plants were characteristically diseased. The Crystalina seed pieces had come from a field which was minutely searched and found to be entirely free from disease. No other cases were found in the entire region, in fact, with the exception of a single stool of L 511 imported from Louisiana.

In July, 1919, a field of D 74 stubble cane, grown for sirup near Cairo, Ga., was found to be healthy with the exception of one corner near the kitchen garden, where about 80 per cent of the plants had the mosaic. Investigation revealed the fact that a patch of green chewing cane had been growing adjacent to the D 74 at that corner during the preceding year. The green cane was found growing elsewhere on the farm this year, and examination showed that every plant had the mosaic disease. Clearly the D 74 had become infected last year, the disease had survived the winter in the stubble, and the shoots were diseased when they appeared again.

At Washington, D. C., 17 varieties of cane, all diseased, are growing in an insect-proof quarantine greenhouse.[1] From time to time healthy sugar-cane plants in pots have been taken into the greenhouse and left exposed to the contagion. Invariably they show the incipient symptoms of the disease on the average in 17 days, proving that the incubation period is from two to three weeks. As has been mentioned elsewhere, sorghum and wild grasses taken into this greenhouse have also become infected. Much more evidence of this kind could be adduced, but it is believed to be sufficiently clear that infection by some principle present only in diseased plants is responsible for the appearance of the disease in formerly healthy individuals.

TRANSMISSION OF MOSAIC IN DISEASED SEED PIECES.

Experiments in Porto Rico[2] and elsewhere have repeatedly demonstrated that cuttings from infected stalks invariably give rise to infected plants. The young shoots are seen to be mottled as soon as they appear. These are referred to as primary infections. The fact is one of far-reaching importance, and to it must be attributed the spread of the disease to new regions, remote from any infected cane, by shipments of cane seed. The use of diseased stalks for propagating results in wider distribution of diseased plants on the same plantation from year to year and insures the survival of the virus, even in the absence of secondary infections. Transmission of the disease in cuttings is a fact, the importance of which can not be overemphasized in view of its obvious bearing on control measures.

[1] Insects were present in the greenhouse.

[2] Stevenson, John A. The "mottling" disease of cane. Porto Rico Insular Exp. Sta. Ann. Rpt. 1916-17, pp. 40-77. 1917. [Literature], pp. 76-77.

TRANSMISSION OF THE DISEASE BY CARRIERS.

It can be proved mathematically that by the law of chance the percentage of diseased plants in a plantation would tend to remain stationary from year to year provided there was no conscious or unconscious selection,[3] if the spread of the disease depended wholly upon the use of infected cuttings. Nature has provided a far more efficient method for the quick dissemination of the malady. Secondary infection, i. e., infection due to the inoculation of healthy plants during the growing season, goes on at a more or less rapid rate wherever the disease has been observed. Secondary infections are easily determined as such when the plants are young. In the case of plants infected in the greenhouse it has been determined that only the leaves which were immature at the time of inoculation and leaves subsequently formed become mottled. When a plant is found with normal leaves up to a certain point on the stalk and mottled leaves above that point it is a clear case of secondary infection. Since in older plants the lower leaves are gradually sloughed off until only a relatively small terminal tuft of the youngest leaves remain when the plant approaches maturity, this method is obviously limited to young plants or to plants with green leaves still present above and below the point of inoculation.

The rate of spread of the disease, as indicated by these secondary infections, varies greatly. Fields are frequently seen in which there has been apparently no secondary infection during an entire growing season. As an extreme case illustrating this point, the fields near Cienfuegos, Cuba, may be cited. There the disease has merely survived by the planting of infected seed pieces, and secondary infection, if it goes on at all, is certainly very limited. Even in Porto Rico, during the height of the epidemic, secondary infection was at a standstill in some localities for a year or more. On the contrary, whole fields of healthy cane became infected in the short space of a month or two. Such a case was the invasion of the variety test field at Santa Rita, Porto Rico, previously mentioned. No doubt the explanation for this great variation in rate of spread by secondary infection must be sought in the mechanics of inoculation. Up to the present no positive proof of the method by which inoculation is accomplished in nature has been brought forward. Reasoning from the fact that new cases often appear at some distance from diseased individuals, it would seem that some agent or carrier is necessary. Mere contact of diseased and healthy plants does not serve to communicate the infection from the former to the latter. In no case has the planting of healthy cuttings in the same pots with diseased plants resulted in the new plants becoming diseased. The same holds true for plants in the field, where healthy plants are often seen with their leaves mingling freely with the leaves of diseased plants for a time much longer than the inoculation period for mosaic, but with no evidence of transference of the inoculum. It is evident that special conditions are necessary in order that the disease can be communicated to healthy plants.

Field observations indicate that acceleration in the spread of the mosaic

[3] Selection is employed where the disease is not recognized. During the beginning of the epidemic in Porto Rico, when sugar was bringing an unprecedented price, it was learned that the manager of one of the mills was instructed to grind the best cane and save the poorest for seed. The "poorest" was undoubtedly that attacked by mosaic.

disease is accompanied with or preceded by severe insect infestation. The cane leafhopper (*Tettigonia* sp.) in particular has been noticed to accompany the rapid spreading of the disease. This evidence is incomplete, but it is supported by the fact that 10 healthy plants placed in insect-proof cages in the greenhouse at Garrett Park, Md., did not contract the disease, while five control plants outside of the cages, but otherwise under identical conditions, all became infected. Aphids were abundant on the diseased cane in this greenhouse, and a few leafhoppers were present. A great deal of experimental work remains to be done before formal proof of the responsibility of any particular insect or insects for the transmission of the disease can be offered.

SOIL RELATIONS.

There has been no indication that the contagion persists in the soil after a crop has been removed and the stubble plowed up. Fields that have been veritable hotbeds of infection after being plowed up and planted with clean seed have only a few scattered cases, which can be accounted for by faulty seed selection. Healthy cuttings planted in the soil of pots from which badly diseased specimens had just been removed grew without any evidence of the disease. The virus does not live over in the soil and it is doubtful whether it exists there at any time. In this respect the mosaic does not by any means present the practical difficulties in the way of control measures to be met with in root-rot. Root-rot, in fact, is to be regarded as a far more serious problem for the Louisiana cane planter than mosaic on this account.

RELATION TO DISINFECTANTS.

Treatment of infected seed pieces by soaking in strong Bordeaux mixture or corrosive sublimate previous to planting has had no effect on the course of the disease. All shoots were typically mottled as soon as they appeared. It was hardly to be expected that superficial disinfection could influence the virility of the infectious principle when all our evidence indicates that the latter permeates the internal tissues, or at least the vascular systems of affected plants.

RELATION TO FERTILIZERS.

Many experiments[1] have been performed in Porto Rico to determine the effect of applying fertilizers, since the claim was made by many planters that mosaic was due to insufficiency of plant nutrients in the soil. Filter-press cake, sulphate of ammonia, and lime in various combinations, together with turning under cover crops and good tilth, had no noticeable effect on the disease as compared with control plats. Standard complete fertilizers were also tried. Beyond a slight stimulation in growth and the darker green color of the treated plants, there was no observed effect. Diseased plants may be expected to respond to good growing conditions the same as healthy ones, but the same constant difference between healthy and diseased plants is maintained under all conditions. The diseased stalks remain below the average weight for healthy

[1] **Stevenson, John A. The "mottling" disease of cane. Porto Rico Insular Exp. Sta. Ann. Rpt., 1916-17, pp. 40-77, 1917. [Literature] pp. 76-77.**

stalks and are just as capable of spreading the disease. Liming the soil has no more effect on diseased plants than the application of fertilizers.

CONTROL.

It is interesting to note that in Java long experience has demonstrated that the disease can best be held in check by careful selection of healthy plants for seed and by replanting fields with cuttings taken from the same field, in preference to buying cuttings of unknown origin or moving the cuttings from field to field on the same plantation. The use of such methods practically amounts to tacit admission of the infectious nature of cane mosaic, although it is ascribed to "bud variation." The facts which have most impressed the Dutch planters are that cuttings from diseased stalks always produce diseased plants and that careless importation of seed is apt to result in increased amounts of the disease.

In the Hawaiian Islands also the disease is controlled by selection of clean seed and the use of resistant varieties.

Measures for controlling the mosaic disease recommended in the following pages are not haphazard expedients, but have been used with very satisfactory results in Porto Rico for more than a year. Planters there have paid a heavy price to learn them, and it is urged that planters of sugar cane in the United States cooperate to prevent a possible epidemic. Indifference to the situation may result in the cane growers being confronted with the fact that it is too late to practice seed selection, as is already the case in western Porto Rico. At present, it will work no particular hardship on the planters to take steps that will reduce the disease to a minimum.

ELIMINATION BY ROGUING.

Roguing consists of pulling out infected plants, root, stem, and branch, and throwing them down between the rows. It is based on the fact that as soon as the plants are wilted they are no longer dangerous as a source of infection. This method is applicable only to fields in which the disease has not obtained a strong foothold. It is not recommended for fields in which the number of infected plants exceeds 5 per cent in half-grown to mature cane or 20 per cent in young plants just sprouting. The size of the field and the condition of surrounding fields with reference to the occurrence of the disease in them must also be taken into consideration. When the field is quite small or consists merely of a few rows or plants of a new variety being propagated for trial on a plantation scale, it should be rogued even if 100 per cent of the plants are infected. Such plants are a constant menace to plants in surrounding fields. In large fields where the proportion of diseased individuals is greater than 20 per cent, roguing is impracticable, not because the plants are any less potent as sources of infection, but because diseased plants produce millable cane, and to destroy considerable quantities of such plants would probably result in greater financial loss than would be sustained by the reduction in yield due to new cases. Large fields with a high percentage of diseased plants should be allowed to mature, but no cane from such fields should be saved for seed.

It is suggested that the following schedule of inspections and roguing be put into operation: In the spring, just as soon as all of the plants have sprouted,

the fields should be inspected by passing up and down the rows. All diseased stools should be pulled out of the ground and cast down between the rows. If this first inspection is carried out in a thorough manner the field will be completely freed from the disease provided no secondary infections are going on. Since there are as yet no certain means of determining the latter fact, a second inspection is essential. It should be made from 25 to 30 days after the first, a lapse of time sufficiently in excess of the incubation period for mosaic to insure recognition of the disease in plants inoculated prior to the first inspection. If no diseased plants are found during the second inspection, it can be assumed that secondary infection is not in operation and that the remaining plants will continue healthy. If diseased plants are found, however, it establishes the fact that secondary infections are going on. The field should be rogued as before, and a third inspection made after the same interval, i. e., 25 to 30 days. If the carriers remain active it may be necessary to repeat the process several times, and owing to the impossibility of recognizing the disease in inoculated plants before the end of the incubation period it is certain that plants which have become infected just before the inspection is made will escape detection. This emphasizes the necessity for making the first inspection early, preferably before leafhoppers or other sucking insects have appeared on the plants.

This procedure may result in perfect control or eradication of the disease or in partial control, the element of uncertainty being due to our inability to control the carriers. By it their activity can be rendered less effective by reducing the sources of inoculum to a minimum. It has effectually halted the progress of the disease into new territory in Porto Rico.

ELIMINATION BY GRINDING ALL CANE AND SECURING CLEAN SEED.

In badly infested sections the problem is manifestly complicated. Where 25 to 60 per cent or more of the plants in large fields are diseased, roguing is obviously out of the question. Such plantings should be allowed to mature. Every stalk of it should be ground, however, and the stubble plowed up and killed. This means, of course, that carefully selected seed must be imported for replanting. Fortunately there is still an abundance of healthy stock in Louisiana and other cane sections in the United States. As a result of its recent exhaustive survey for mosaic disease, the Office of Sugar-Plant Investigations of the Bureau of Plant Industry is in a position to furnish information on the nearest or most accessible source of clean seed for any region. Data have been secured on the prevalence of other diseases and insect pests in all cane regions, so that reasonable security against the dissemination of other cane maladies is assured.

EXCLUSION.

There are at the present time (October, 1919) a number of large cane areas in the United States not yet invaded by the mosaic disease. Cane planters in these areas should urge the enactment of State legislation prohibiting the importing of cane into them from any source whatever until such time as it can be accompanied by an authentic certification of health. Such areas include the entire Bayou Teche district and the parishes to the north in Louisiana, consisting of St. Mary, Iberia, Vermilion, Lafayette, St. Martin, Acadia, St. Landry,

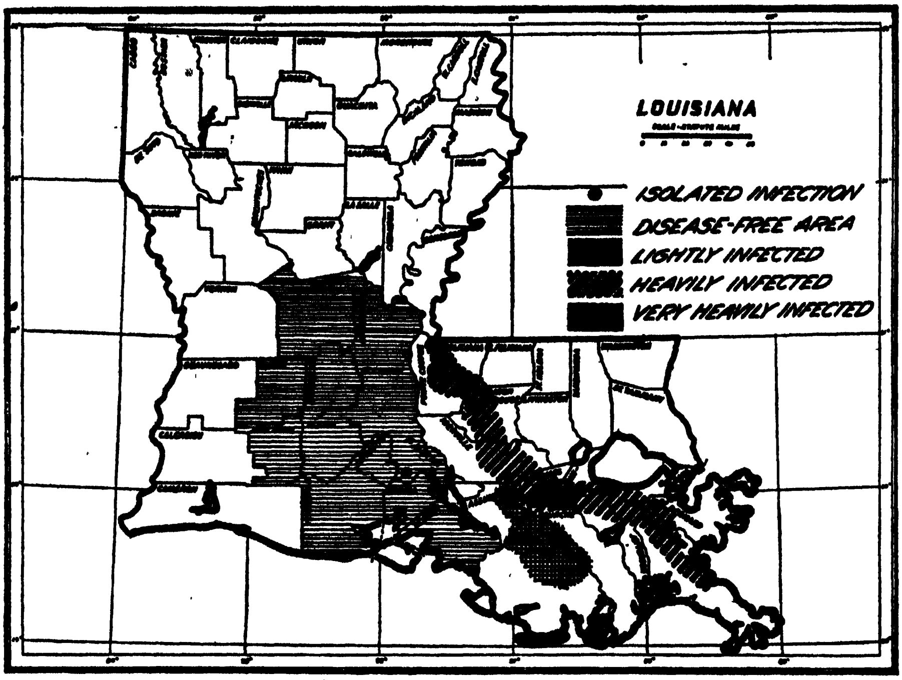


Fig. 3. Map of Louisiana, showing the location of diseased areas of sugar cane in that State.

Avoyelles, and Rapides. This is, of course, the most important disease-free area. (Fig. 3.) Other similar areas are the entire State of Mississippi with the exception of Biloxi; the entire State of Alabama except a small locality near Muscogee, Fla.; the entire State of Georgia except Grady County; and all parts of Florida other than those indicated in Figure 4.

ERADICATION.[1]

Where the disease is present in small amount and in few well-defined areas, the possibility of quick and complete eradication exists. Such conditions are found in Mississippi, Alabama, and Florida. (See Fig. 1.) The cane in these areas should all be ground during the present harvesting season and the stubble plowed up. As a precautionary measure, some crop other than a grass should be grown on the land for one year, after which cane may again be grown with safety. The two small infested areas in Alabama and Mississippi offer no difficulty at all. They can be destroyed with practically no loss to the owners, and the assurance of healthy crops in the future more than offsets the inconvenience of growing some other crop on the land now occupied by infected cane. The success of the measure in Florida is made possible by the present organization of the State plant board, which has already met the test of successfully handling more serious problems.

ELIMINATION BY PLANTING IMMUNE VARIETIES.

Success of the control measures suggested up to the present depends entirely upon the whole-hearted cooperation of all cane growers. There yet remains a

[1] In so far as it applies to the regions indicated, we concur in this suggestion by Mr. Wilmon Newell, Plant Commissioner of Florida.

method, applicable only to certain regions, by which a planter can make himself wholly independent of any default on the part of his neighbors. A few varieties of sugar cane have been discovered that are absolutely immune to mosaic under all conditions. Most of them are of the type referred to as Japanese cane. Their origin is obscure. They have certain characteristics in common. All are tall growing with slender stalks. They stool abundantly, ratoon well, and produce an enormous tonnage. The sucrose content is not so high as in some of the broad-leaved canes, but in sugar per acre they take first rank with the best existing varieties. The Kavangire, Zwinga, Uba, Cayana 10, and numerous others imported by the office of Foreign Seed and Plant Introduction are included among these varieties. The Cayana 10 has already won a well-deserved popularity among the farmers of the cane-sirup section in Georgia and northern Florida on account of its high tonnage and the excellent quality of sirup made from it. The Kavangire is used for manufacturing sugar in Argentina. Its estimable qualities are brought out in Table 3.

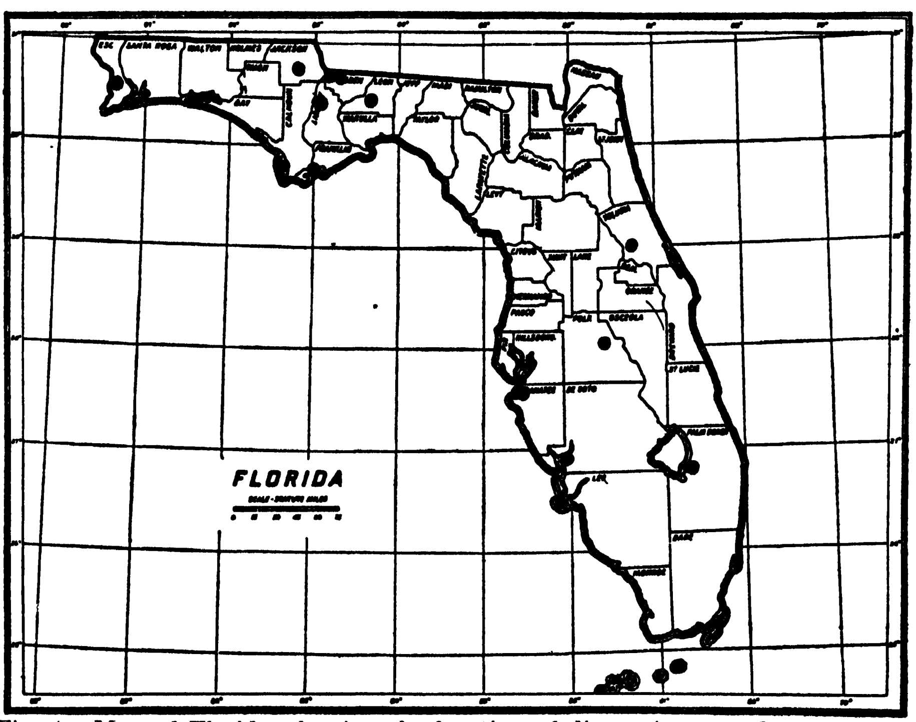


Fig. 4. Map of Florida, showing the location of diseased areas of sugar cane in that State.

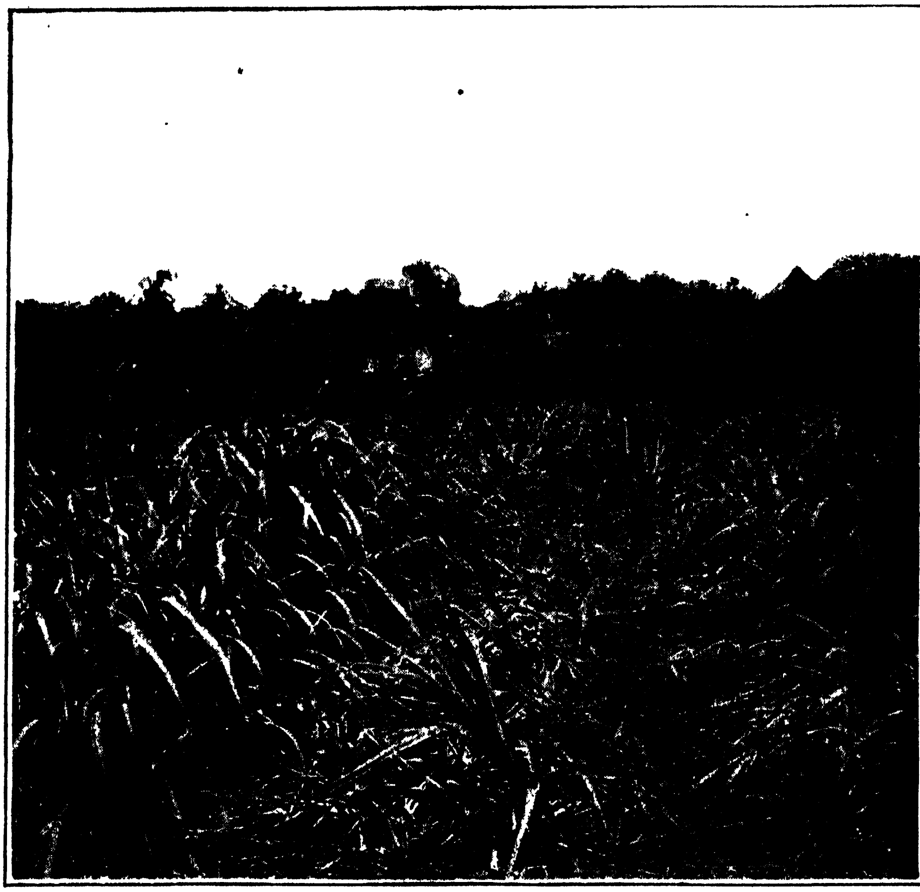


Fig. 5. Kavangire sugar cane (immune), at the left; G. C. 1070 (susceptible), at the center; Java 36 (susceptible but tolerant), at the right.

TABLE 3.—YIELD AND ANALYSIS OF KAVANGIRE SUGAR CANE COMPARED WITH OTHER STANDARD VARIETIES.[1]

Variety	Average Weight of Single Canes	Weight of Cane per Hectare[3]	Brix Scale	Sucrose	Purity	Weight of Sugar per Hectare[3]
	Kilos[2]	Kilos[2]	Deg.	Pct.	Pct.	Kilos[2]
Kavangire	0.68	166,850	17.84	15.68	87.5	16,090
Java 36	1.36	117,300	17.55	15.34	87.4	11,024
Java 213	0.84	95,725	17.54	15.79	89.96	9,533
Louisiana 60	1.87	118,125	17.32	15.34	87.05	10,973
Java 139	1.10	89,975	16.67	14.41	86.40	7,853
Rayada (Louisiana Striped)	1.71	94,150	18.26	16.39	89.74	9,714
Java 234	0.95	75,550	19.02	16.66	87.08	7,703
Morada (Louisiana Purple [?])	1.28	72,925	16.69	14.54	87.07	6,354
Honduras	1.23	76,575	16.98	14.36	83.88	5,998
Java 100	1.00	79,675	16.03	13.57	89.68	6,456
Tamarin	0.95	33,325	19.15	17.50	91.54	3,940

[1] Bennett, A. G. Informe de subestaciones para el año 1914. In Rev. Indus. y Agr. Tucuman, año 5, pp. 208-209. 1914.

[2] A kilo is the equivalent of 2.2 pounds.

[3] A hectare is the equivalent of 2.47 acres.

Figure 5 shows a row of Kavangire cane on the left; a susceptible variety, G. C. 1070, at the center; and a diseased but tolerant variety, Java 56, on the right. Unfortunately, the Kavangire variety is a long-season cane and therefore not suitable for conditions in Louisiana. The possibility of breeding more early maturing varieties from these parents is being investigated.

Several of the broad-leaved varieties of cane originated at the Sugar Cane Experiment Station at Aubudon Park, La., appear to be immune. Although equally exposed to the contagion, no individuals of these varieties have become affected, while practically every plant of the scores of other varieties surrounding them is diseased. They have been under observation for too short a time, however, to demonstrate that their apparent immunity is permanent.

Kavangire, a Cane Variety Immune to Yellow Stripe Disease.

During the past few months reference has been made to a cane variety called Kavangire, which was attracting attention in Porto Rico owing to its immunity to Yellow Stripe disease. Such descriptions as were given indicated that Kavangire was similar to the spindling cane known locally as Uba. The matter is clearly set forth in a circular recently issued from the Porto Rico Agricultural Experiment Station. Under the heading, "Japanese Cane," we read:

"Several years ago the U. S. Experiment Station, Mayaguez, P. R., received from the U. S. Department of Agriculture, Washington, D. C., a variety of Japanese cane, which was planted extensively in the Southern States for forage. Two years ago the Station received from George L. Fawcett, former pathologist, now connected with the Station at Tucuman, Argentine, some Japanese cane from over there. It is known as Kavangire, and is grown very largely in Argentine, where they are greatly troubled with the mottling disease that is giving us at present considerable concern in Porto Rico. Both of these canes are free from the disease at the station in Mayaguez. When fully mature they appear very much alike, but when younger the difference is more noticeable. The cane received from the U. S. Department of Agriculture may be the one known as Zwinga. Until we are better informed we will, at least, put it under that name. We have received a few tons of this latter cane from the U. S. Experiment Station at St. Croix, Virgin Islands, and distributed it widely here. Dr. Longfield Smith, the director, writes that it is producing 50 tons to the acre. The sucrose content of same is 12 per cent. He considers this remarkably good when the cane is not mature at present; also the yield is good for St. Croix, where they have an average rainfall of less than 50 inches. This cane, with us at Mayaguez, has shown the following analysis: Brix, 15.4; per cent sugar, 12.5; purity, 81.1. We have no estimates of the yield at present. The Kavangire at Mayaguez has given, from the plot, a yield calculated at 83 tons per acre. The next highest of a large number was 52 tons. During the present crisis we urge the planting of these two canes, and we are making every effort possible to secure seed. They have the very high recommendation that they are immune to the

mottling disease. On the other hand, they are very slender canes, which will increase the labor of harvesting; also, the sucrose content is much lower than some of our seedling canes. However, with their tonnage and freedom from disease, they are, from present outlook, the greatest producers of sugar in those sections of the island that are afflicted with the mottling disease.

"We have at the Station also two Java seedlings that, while not immune to the disease, yet the damage caused by it to them is slight. One, especially, Java 36, gave a yield of 52 tons of cane, and the sucrose content was 17.25 per cent. The damage from the mottling disease was small. A number of other seedlings, also, are promising, namely, Barbados 1753, Guanica Centrale 1480, Guanica Centrale 1313, Mayaguez Station No. 3 and No. 4. From the many canes bred at the Insular Station, Rio Piedras, Guanica Centrale at Santa Rita, Fajardo Sugar Co., Fajardo, and U. S. Experiment Station, Mayaguez, it is very probable that we will be able to select canes that, while giving large yields in sugar per acre, will at the same time prove but slightly subject to the mottling disease. In the meantime, our best hope is in the Japanese canes while we are seriously affected by this trouble, and every planter living in a section where this disease prevails is urged to undertake growing the Japanese canes for the purpose of securing seed for more extended planting during the coming year. In this effort the U. S. Experiment Station will lend every aid possible, distributing all the seed that can be possibly secured both at home and those obtained from the Station in St. Croix. We must remember, however, that the Japanese varieties are inferior canes and we must seek good improved canes that, while perhaps only partially immune to the mottling disease, are sweeter, more easy to harvest and far superior in milling qualities and yield of sugar to the Japanese canes."

[H. P. A.]

THE HAWAIIAN PLANTERS' RECORD

Volume XXII. MARCH, 1920 Number 3

A monthly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

Our Forestry Problems as Seen by Hillebrand in 1856.

Elsewhere in this issue of the *Record* is reprinted a paper read before the Royal Hawaiian Agricultural Society at its sixth annual meeting by Dr. Wm. Hillebrand. This meeting took place in 1856, but the salient points of Dr. Hillebrand's making, apply with extraordinary accuracy to the matter of forestry in relation to agriculture, as the subject confronts Hawaii today.

Dr. Hillebrand at that time said with unmistakable significance, "As long ago as 1804, Alex. von Humboldt * * * warned that the waste of forests entailed two evils on the following generation: a want of fuel, and a deficiency of water. The reality of the first is self-evident; the second * * * a statement which, if substantiated entailed important consequences, was well worthy to arouse a general attention. * * * Such a mass of evidence has been accumulated that the theory may well be said to have been converted into a doctrine."

Proceeding by way of an unusually interesting exposition of "the influence of forests upon the absolute quantity of rain or precipitate of atmospheric moisture," Dr. Hillebrand offered illustrations convincingly definite, and covering an enormous field.

Of local conditions he spoke freely. "It cannot be denied," he said, "that in many places the domain of the forest has been seriously encroached upon by man, and more by cattle." The paper invites quotation, and repays reading. It is something to know that so early as 1856 attention was being called to the "startling fact" that "the whole plateau of Waimea in Hawaii has been spoliated entirely of its original forest which only twenty-five years ago formed an impenetrable thicket, by the agency of wild cattle."

"Of all the destroying influences man brings to bear on nature," said Dr. Hillebrand some sixty-odd years ago, "cattle is the worst."

Certain parts of these Islands offer no less substantial testimony to the truth of that dictum now than then.

It appears toward the last of the paper that Dr. Hillebrand was sanguine of local reforestation. "Nowhere, I imagine, shall we have to wait more than six to eight years before some results are obtained. * * * It is my opinion that on the banks of rivers, and in low, wet places our end may be attained in less than

four years." He spoke of results in his Honolulu garden where some introduced species grew in little more than one year to a height of twenty-four feet, and others ten and sixteen feet.

It is interesting that the Hawaiian Sugar Planters' Association has established a tree nursery adjoining the Hillebrand garden, and through the courtesy of Mrs. Mary E. Foster is now utilizing seed of the trees planted there by Dr. Hillebrand.

Dr. Hillebrand pointed out the necessity of protecting the native forests, and making the most of the native flora, but at the same time he realized the wisdom of strengthening the Hawaiian forests by introduced species. He favored the importation of seeds from abroad in quantities for distribution,—the appointment of wardens for the protection of the watersheds.

He felt that once our naked hills hills are properly reforested, "springs will soon bubble forth again from every nook and corner, between rocks and from under the fern-tree, to unite in streams which encased in a framework of bamboo canes and lianes will pour out of every valley and cover with fertility the now arid and sterile plains."

Many of these plains of Dr. Hillebrand's day have since been converted into sugar plantations by virtue of hydraulic engineering operations that have brought water from great distances, or from artesian sources. These enterprises have increased in a marked degree our dependence upon watershed forests. There is little in his exceedingly interesting paper that does not apply as vitally to the Hawaii of today as to the Hawaii of 1856.

Deterioration of Cuban Sugars.

In the report of the New York Sugar Trade Laboratory for 1919, by Dr. C. A. Browne, the following statement is made in regard to the loss of sugar in Cuba due to deterioration:

"A slight improvement was noted in the quality of the raw sugars tested during 1919, although the character of the product received in the latter part of the year was very inferior owing to its having undergone deterioration in storage. The losses from this cause in 1919 were probably the greatest in the history of the sugar industry. The loss during storage in Cuba alone, according to comparative analyses made at the Laboratory, is estimated at over $5,000,000, and when there is added to this sum the losses from deterioration in transit and in storage after delivery, the total losses from this cause in 1919 probably approximate one per cent of the total value of the Cuban crop."

We are luckily free from this kind of loss in Hawaii on account of the low moisture content and sanitary conditions of manufacture of our commercial sugar.

R. S. N.

Information for the Irrigator.*

By R. M. Allen.

Introduction.

Of all the factors influencing the productive capacity of the soil, there is none more important than soil moisture, which, in turn, in irrigated sections, is dependent on irrigation. We have more crop shortage from lack of moisture than from any other cause. The fertilizer which we apply in such large quantities is not available except when in solution, and without soil moisture it cannot pass into this state. Most plants contain from 70% to 90% water, and it has been found on the coast that it takes from 400 to 900 pounds of water to produce 1 pound of dry matter. We find that sugar cane contains from 60% to 70% moisture, and that it takes from 100 to 300 pounds of water to produce 1 pound of cane. For an ordinary crop this means from 10,000 to 20,000 tons, or a depth of from 7 to 14 feet of water per acre. Soil bacteria require moisture to make nitrogen and the mineral elements of plant food available. There is the closest relation existing between moisture in the soil and plant growth.

Expressing this in terms of dollars and cents, we see the relative importance of irrigation compared with other field operations.

In 1913-14, on wholly and partially irrigated plantations, $15,000,000 was spent in field operations. Out of this, $4,500,000, or 30 per cent, was for irrigating—including pumping, labor, and water costs. $2,700,000, or 18%, was for fertilizer, and $2,400,000, or 16%, was for harvesting. The balance was distributed in smaller amounts in planting, cultivating, etc. The point to bear in mind is that our irrigating cost is by far the largest single item in the field expense. Figures also show that 60% of the total irrigating cost is spent on labor, 30% on pumping, and the balance on the minor items.

Because of the large amounts of water used in the production of our crop, and because of the high cost of applying this, we are not wasting attention spent on the beneficial, economical use of water, which means the elimination of the losses, and the intelligent application of the water reaching the field.

Conveyance Losses from Pump to Field.

Probably the first loss occurs, assuming that the pumps are working properly, in seepage in the main ditches leading from the pump outlet to the reservoir. This has been found to run as high as 50% a mile, in exceptional cases, but frequently as high as 25% a mile. This, of course, will vary greatly, depending on the texture of the soil and subsoil, the position of the water table and natural drainage conditions, the age of the ditch, the depth of water, and its velocity. The remedy is lining the ditch, and where water is scarce, or where

* A lecture presented at the Short Course for Plantation Men, October, 1919.

it is pumped to high elevations, this is well worth while. The initial cost may seem high, but when the saving in water and the upkeep of the ditch are considered, it is realized that the expense is justified. A point to be impressed here is that the seepage in some ditches is greater than in others; in fact, many old ditches, in a compact soil, will be found in which no seepage occurs at all. Before any amount of money is spent on lining a ditch, measurements should be made to determine the extent of loss. Some ditches will require lining sooner than others.

Another loss occurs in the level ditches, but from the nature of their location they canont be lined. The remedy for this is to avoid running small heads of water in them. Frequently one or two men's water are used several days in succession when four or six men's water one day will do the same work at a lessened loss by evaporation and seepage. The percentage of loss is always smaller with large amounts of water than with small amounts of water. Hence the practical suggestion here is not to fill the level ditches any oftener than is necessary. This is well illustrated in the case of one manager on Kauai, who has a four-mile main ditch from which four or five gangs are supplied with water. Under his ordinary practice it would take thirty days to irrigate the area controlled by this ditch. Recently, however, being short of water, he has combined these small gangs into one big gang, and now not only covers the same area in twenty-two days, but has ten men's water more at the lower end of the ditch than he had before. With his one large gang closer supervision is also possible.

The losses occurring in the watercourse can only be lessened by carefully shutting the water in each line. This is not a serious loss, for it all reaches the cane at one place or another.

Disposal of Water that Reaches Field.

The water that finally reaches the field, probably only 40% to 60% of the water pumped—I speak of pumped water because it has a greater value, although mountain water may be equally valuable in time when water is scarce—is disposed of in four ways:

1. By surface run-off or waste.
2. By soil evaporation.
3. By plant transpiration.
4. By deep percolation.

The correct "economical use" of water is obtained when the above stated losses are reduced to the minimum.

Surface run-off is a loss due to leaky gates, and general careless, poor methods of irrigating. This is of minor importance, and on our large irrigated areas, closer supervision, particularly in big cane, is impractical.

Soil evaporation is automatically regulated by the cane closing in, and by the natural mulch that is formed by the self stripping of cane. In California, particularly in orchards, this loss is controlled by mulches of various sorts,

either soil mulches formed by cultivating to different depths, or by artificial mulches of straw. Our high humidity has an additional effect on checking this loss.

Transpiration is the natural process by which a circulation of plant foods in solution is maintained in the plant, or is the action through which the water serves a useful purpose. However, this action also takes place in weeds, and therefore the fewer the weeds, the cleaner the field, the more moisture that is available to the cane plant.

Thus it is that the loss with which we are most concerned is that occurring from deep percolation, by which I mean the passage of water, not retained by the soil, to depths below the zone of root growth. The useful water in the soil, known as the capillary water, is held by means of a thin film of water around each soil particle. Consequently, the soil having the greatest number of soil particles for a unit area is capable of holding the greatest amount of water. An acre foot of clay soil is composed of particles which have an estimated aggregate surface area of 16,000 acres, a loam soil 10,500 acres, and a sandy soil 3250. If a certain depth of irrigation water is applied to a loam soil and a sandy soil, any foot section of the former will retain more of the water than the same area of the latter, due to smaller, more numerous soil particles, and consequently greater area for the moisture films to form. As it is beyond our power to modify the size of the soil particles, it is up to us not to apply more water than our soils can hold.

Under our conditions, where the irrigating cost is so high, and our crop is so entirely dependent (in irrigated sections) on artificial irrigation, this is a point that cannot be emphasized too strongly. The object of an irrigation is to supply water to the plant roots. Now, the cane plant seldom sends roots more than four or five feet deep. Thus the water that we apply should all remain above that depth. At our Waipio Substation we have traced the movements of water to a depth of six feet under a 2″, a 6″, and a 9″ irrigation. We find—and the results are in accordance with data that have been secured elsewhere—that 3% of a 2″, 47% of a 6″, and 65% of a 9″ irrigation pass to depths below six feet. This was determined by sets of soil samples taken before and after the irrigation, and the increased percentage of moisture determined. The figures further show that, under Waipio conditions, it is impossible to store more than 4½ inches of water in the upper six feet of soil. This means that when more water than that is put on one of our fields, it passes below the reach of plant roots.

This point has several very practical connections. First, let me state that this figure, 4½ inches, or 122,000 gallons in six feet of soil, is for an ordinary loam soil. It would be much less for a sandy or gravelly soil, and greater for a finer-textured soil.

When fertilizer is put on with the irrigation water, and 40% or 50% of the latter passes below the root zone, it is easily seen that it carries with it some fertilizer, and the result is a triple loss—water, fertilizer, and the extra labor of putting the larger amount on.

Another application of this point is that it is impossible, above a certain point, to give a field a heavy irrigation and expect it to last longer than a lighter

irrigation, simply because a soil can only be made to hold a certain fixed amount of water.

A third and very important application is in connection with the first four or five waters on a plant field. It is generally true that small amounts of water will wet a soil to great depths, and that a large percentage of a heavy irrigation is wasted even on big cane with a fully developed root system four to five feet deep. A greater loss must therefore occur when a plant field, having a very shallow root system, is given anything but a very light irrigation. It has been noticed on most plantations that the irrigators fill the lines in a plant field just as full as possible. The larger the line, the more water that is put in. In an ordinary furrow this is enough water to wet the soil to a depth of at least eight feet, whereas it is only necessary to wet it to a depth of two feet at the most. If the hana-wai men can be trained to shut the water off before it reaches the end of the line instead of shutting it off after it has completely filled the lower end of the line, far better results will be obtained. This can be easily tried on any plant field by picking out two or three watercourses and instructing a man to run the water one minute in each line. You will find that the ordinary practice is to run it from two to four minutes. I believe that under any condition your watercourse that has had the smaller amount of water will come up just as rapidly, and germinate just as well as the balance of the field. This has an effect on the whole plantation, giving extra water and labor to the big cane, and allowing more frequent irrigation to the plant cane. Two small irrigations on plant cane, particularly H 109, are much more economical than one large irrigation.

A fourth point is that it is a bad practice to saturate a soil with water. Plants need air as well as water, and whenever water is put into the soil, an equal volume of air is displaced. To saturate a soil with water means to displace all the air, for when the spaces between the soil particles known as the "pore space" are not filled with water they are filled with air.

Water continually passing to lower depths will sooner or later raise the water table. This will vary greatly with conditions, but a rising and falling water table is always injurious to crops. A line must be drawn here between a water table that is always near the surface, and one that rises there only after an irrigation to recede slowly between irrigations. Alfalfa grows very well in California in some sections where free water is never less than three feet from the surface, while in other sections it is killed by free water that rises all of a sudden to five or six feet from the surface. Cane, as any other crop, will adjust itself to constant conditions, but it cannot vary its growth to meet sudden changes.

In this connection it should be noted that when irrigation water contains an appreciable amount of salt, it is essential that an excess of water be added to leach out the added salts. It is an open question whether this should be done through adding an excess amount of water at each irrigation, or by excessive irrigations periodically. Great care should be observed here, as heavy irrigations raise the water table and are liable to concentrate the salts near the surface, rather than leach them out.

California studies on the duty of water on alfalfa have brought to light some very interesting facts along this line.

(1) On five fields only one-third of the water applied to silt loam soils was retained in the upper six feet of soil where the principal root development of the alfalfa plant is located.

(2) The average quantity of water retained per acre foot of soil was 0.92 inch for silt loams, 0.71 inch for silts, 0.58 inch for clay loams, and 0.37 inch for clays.

(3) The general conclusion from all the California work is that without a doubt the prevailing practice was to apply far more water at a single application than the more porous soils can retain, and than the heavier soils can absorb.

A single comparison will show what is meant by this. On a certain clay loam field where 16 inches of water were applied, 4½ inches were retained by the upper six feet of soil, while on an adjoining field of the same texture, 7½ inches were applied, and 4 inches found in the upper six feet of soil. The smaller irrigation was thus doing the same work as the larger irrigation.

Meaning of Heavy and Light Irrigations.

The question very naturally comes up, "What is a heavy or light irrigation, and how do we know which we are doing?"

Before a discussion of this can be taken up, it is necessary to mention a few of the terms used in expressing amounts of water. Probably the most familiar expression is that 1,000,000 gallons will irrigate 100 acres. Now, there are two units of measurement:

(1) Those used to express the rate of flow or to express volume of water in motion. For example, we say that such and such a pump delivers 1,000,000 gallons per 24 hours.

(2) Those used to state a definite volume of water—at rest. For example, we say that 1,000,000 gallons per acre were used in such and such a field last year.

Now, although these are the units used by us to express water, they are clumsy and really convey no meaning. 1,000,000 gallons per acre means nothing to you or to me. It cannot be measured with a ruler, and it is hard to conceive what this would look like over an acre. If, however, you know that 1,000,000 gallons over an acre is equal to 3 feet of water over the same area, you have a definite idea as to how much water that is. This is a definite relation existing between 1,000,000 gallons and the unit known as an "acre foot," which is a depth of water of one foot over an acre. Two acre feet means a depth of two feet over one acre. The smaller unit generally used in expressing the amount of a single irrigation is the "acre inch." (As the name suggests, twelve acre inches are equal to one acre foot.) It means a depth of water of one inch over an acre. The only relation that is necessary to remember is that 1,000,000 gallons (I am speaking now of water not in motion) are equal to three acre feet. As a matter of fact, this is 3.07 acre feet, but it is sufficient to remember the even number. From this, of course, 2,000,000 gallons are equal to six (exactly 6.14) acre feet, or one acre foot is equal to 326,000 (exactly 325,850) gallons. On the

other hand, if you know that 1,000,000 gallons (three acre feet) were put on three acres, you also know that one acre foot went on each acre.

Now, when your pump engineer tells you that a pump is throwing 1,000,000 gallons, he means that you are getting 1.55 cubic feet every second. This is the unit known as the "second foot." One second foot, or one cubic foot per second, is equal to 450 (448.8) gallons per minute, or 650,000 (646,272) gallons per day. These figures may seem clumsy, but they are given because there is a definite, simple relation between water at rest and in motion where this system of expressing water is used, namely:

One second foot flowing for 24 hours will cover one acre to a depth of two feet (1.98), or it will deliver two acre feet.

Remembering this, it is easy to calculate what happens when ten second feet flowing for 12 hours covers 40 acres. Ten second feet for 24 hours equals 20 acre feet. Ten second feet for 12 hours equals 10 acre feet. Ten acre feet over 40 acres equals 0.25 acre feet or 3.00 acre inches on each acre.

Now, to come back to our familiar expression, 1,000,000 gallons per 100 acres. This does not convey any very great impression to us. However, 1,000,000 gallons equals 1.55 second feet, which in 24 hours, or one day, gives 3.10 acre feet. In 365 days we have 1132 acre feet over 100 acres, or 11.32 feet over 1 acre. Thus, 1,000,000 gallons per 100 acres means approximately 11 feet of water over each acre. This illustrates very clearly why the second foot-acre foot units are easier to handle. We can conceive of 11 feet of water on each acre. Assuming that we irrigate twice a month, this is 24 5½-inch irrigations, or 149,000 gallons.

From our experience so far in irrigation we speak of anything over a five-inch irrigation as heavy, and anything under as a light irrigation.

This also illustrates the two methods of expressing what is known as the "duty of water," which is the acreage served by a quantity of water, namely:

(1) In acres served by a given unit of flow.
(2) In acre-feet per acre.

In irrigation, the duty of water means the amount of water applied per acre in the production of a crop. When the amount of water per acre used is small, the duty is high, and when a large amount is used per acre, the duty is low. In the States the duty varies greatly. In California the duty ranges from 1 second foot to 200 acres to 1 second foot to 120 acres, a high duty compared with Utah, where a duty of 1 second foot to 20 to 70 acres is prevalent. A duty of 1 second foot to 20 acres means 36 feet per acre per year, or 12 acre feet in four months, which is the average irrigating period on the Coast. Only 2½ feet are needed to produce a crop in the locality, hence the extravagant waste of water is seen.

As has been stated, our duty of "1,000,000 gallons per day per 100 acres," or 1.55 second feet per 100 acres, which is 1 second foot to 64 acres, means a depth of 11.3 feet of water on each acre per year. Whether this is a high or low duty we are at present unable to say.

This brings us to a few calculations that should be made to check up our irrigation practice.

(1) I have a flow of 10,000,000 gallons (15.50 second feet). How many acres will that handle, giving a 4-inch irrigation (108,000 gallons) every 20 days?

1 second foot = 2.0 acre feet per day.
15.50 " " = 31.0 " " " "
15.50 " " = 31 x 20 = 620 acre feet in 20 days.
4 acre inches = 0.333 acre feet per acre.

$$\frac{620}{.333} = 1860$$ acres which can be given a 4-inch irrigation every 20 days with the above flow. The duty in this case is:

15.50 second feet to 1860 acres.
1 " foot to 120 acres, or
1,000,000 gallons to 186 acres.

(2) Take a reverse proposition. A plantation has 4000 acres which should be given a 4-inch irrigation every 20 days. How much water is needed?

4 acre inches = 0.333 acre feet on each acre.
4000 $\times$ 0.333 = 1332 acre feet needed.

Now, how great a flow will in 20 days give 1332 acre feet?

1 second foot in 1 day gives 2 acre feet.
1 second foot in 20 days gives 40 acre feet.

How many second feet will in 20 days give 1332 acre feet?

$$\frac{1332}{40} = 33.3$$ second feet or 650,000 $\times$ 33.3 = 21,600,000 gallons.

(3) A third, and probably the most practical question, is: If I am being given a flow of 20,000,000 gallons per day, and I am irrigating 2000 acres every 20 days, how much water am I giving per irrigation?

20,000,000 gallons = 31.0 second feet.
1 second foot in 1 day = 2 acre feet.
31 " feet " 1 " = 62 " "
31 " " " 20 days = 1240 " "

This 1240 acre feet is distributed over 2000 acres. Therefore each acre is getting $\frac{1240}{2000}$ = 0.62 acre feet, or 7.4 acre inches (201,000 gallons).

The main value of these calculations is that it will enable you to get an idea as to how you are using your water. It is safe to say that the maximum amount of water that the cane can use is five or six inches every two weeks, and in some cases I think it will be found that much more is being used.

Three factors must be known before the amount or depth, as we more properly call it, of an irrigation is known: Amount of flow or discharge; time of flow, and the acreage. The last two are simple. Generally we know that it takes one man one hour or two hours to irrigate one watercourse which is 0.25 of an acre. (This varies, of course, but it is easily determined.) It remains, therefore, only to determine the flow, or what a "man's water" in Hawaii, or "head" in California, really is. There are many ways of measuring water, but for our purposes we need only consider four:

1. Weirs.
2. Current meters.

3. Surface flow method.
4. Rating flumes.

This is a very large subject. Many volumes have been written on it, so only the basic facts will be mentioned. I have already discussed the units of measurement. The second foot-acre foot unit is the one universally used, and all tables for weirs and current meters are based on this.

The weir is the most common device for measuring water, because it is cheap, simple to construct, and, when properly installed, is accurate. Three types are most common—the trapezoidal or Cipolletti weir, the rectangular weir with end contractions, and the triangular weir. The Cipolletti weir has been very popular because of the fact that with a given head the discharge was proportional to the length of the crest; that is, six inches on a two-foot weir would give twice the discharge of six inches over a one-foot weir. However, accurate tables are available for rectangular weirs, and as this type is easier to construct, they are to be preferred for our purposes. Triangular weirs are used for measuring small heads of water, which they do more accurately than the other types. They are simple to construct, and can be used in watercourses to measure one man's water. The conditions required for accuracy in the above-mentioned weirs are about the same, and are as follows:

1. The upstream crest should be sharp and smooth.
2. The distances of its crest and sides from the bottom and sides of the ditch should be not less than twice the depth of water over the weir, and never less than one foot.
3. The overflow sheet should only touch the upstream edge of the notch. If made of wood it should be beveled.
4. Air should circulate freely on all sides of the sheet.
5. It should be level and vertical.
6. The measurements should be taken from 4 to 10 feet upstream. Generally a post is put in, and a nail driven at exactly the same elevation as the crest of the weir. This nail can be approximately set by means of an ordinary carpenter's level and a piece of board. Then, when the water is turned in, it can be accurately set, using the water as a level. The measurement is then made by means of a ruler, placing zero on the nail thus set. This may be either in inches or in tenths of feet. Formulae are given for the discharge over weirs of various types, but it is unnecessary to know these, for tables are readily available which give the discharge over weirs of different crest lengths. For convenience in using these it is best to make weirs with a crest of even-foot and half-foot lengths.

There has recently come to our attention a device known as the "Lyman Irrigation Meter," which, if it proves successful, will increase the efficiency of weirs many times. This device measures and records all the water passing over the weir, regardless of the changing level in the ditch. One of these has been ordered, and as soon as tests have been conducted, a report will be made on it.

Where the fall in the ditch is great, it is best to have a short crest, and consequently a greater depth, while with a medium grade a longer crest, and consequent shorter depth, is desirable. Generally speaking, the depth of water flowing over the crest should not be greater than one-third of the length of the crest.

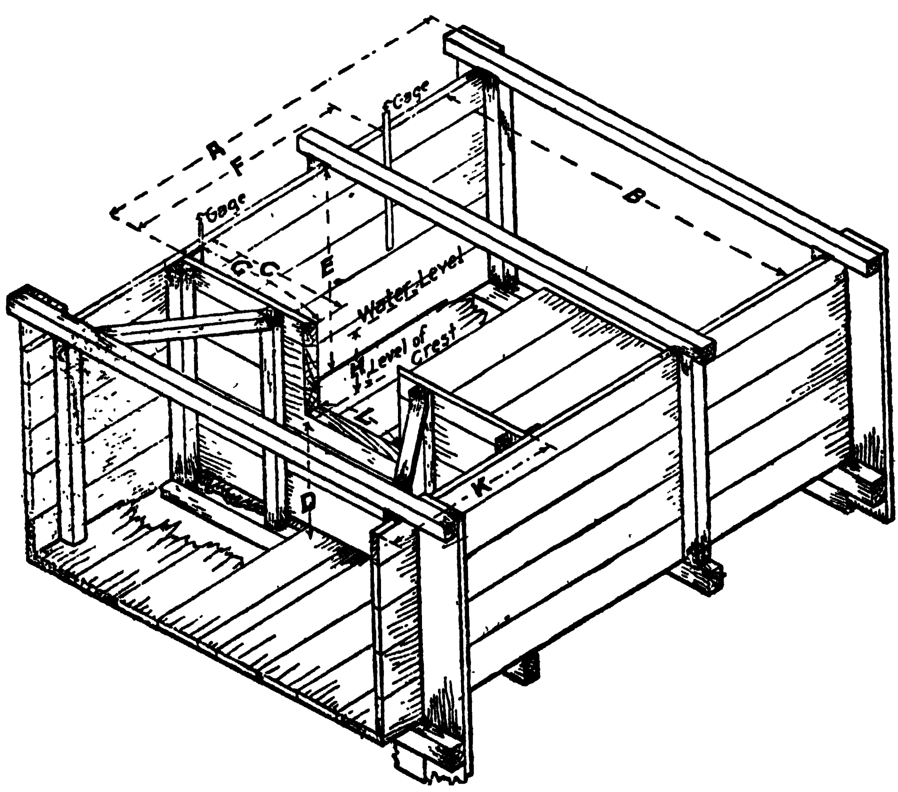
Table 1, taken from Farmers' Bulletin 813, by V. M. Cone, Irrigation Engineer, gives the sizes of weirs best adapted to measuring streams of water varying from one-half to twenty-two cubic feet per second (323,000 to 14,000,000 gallons per day).

TABLE 1.—WEIR BOX DIMENSIONS FOR RECTANGULAR AND CIPOLLETTI WEIRS.

(All dimensions are in feet. The letters at the head of the column refer to Fig. 1.)

RECTANGULAR AND TRAPEZOIDAL WEIRS WITH END CONTRACTIONS.

Flow		H	L	A	K	B	E	C	D	F
Sec. Feet	Million Gallons per 24 Hours	Maximum head.	Length of weir crest.	Length of box above weir notch.	Length of box below weir notch.	Total width of box.	Total depth of box.	End of crest to side.	Crest to bottom.	Point of measurement upstream from crest.
½- 3	323,000- 1,900,000	1.0	1	6	2	5½	3½	2¼	2	4
2- 5	1,300,000- 3,230,000	1.1	1½	7	3	7	4	2¾	2½	4½
4- 8	2,600,000- 5,170,000	1.2	2	8	4	8½	4½	3¼	2¾	5
6-14	3,900,000- 9,000,000	1.3	3	9	5	12	5	4½	3¼	5½
10-22	6,500,000-14,200,000	1.5	4	10	6	14	5½	5	3½	6



Plan of weir box. Weir may be placed in box built of lumber or cement, or in enlarged section of ditch.

It is stated that weir boxes of these sizes will give results within one per cent of the correct values, providing the above-mentioned conditions necessary for weir crests and sides are followed.

TABLE 2.—DISCHARGE TABLES FOR RECTANGULAR WEIRS.*

Head in Feet	Head in Inches	Discharge in Cubic Feet per Second for Crests of Various Lengths				
		1 Foot	1.5 Feet	2 Feet	3 Feet	4 Feet
0.20	2⅜	0.291	0.439	0.588	0.887	1.19
.21	2½	.312	.472	.632	.954	1.28
.22	2⅝	.335	.505	.677	1.02	1.37
.23	2¾	.358	.539	.723	1.09	1.46
.24	2⅞	.380	.574	.769	1.16	1.55
.25	3	.404	.609	.817	1.23	1.65
.26	3⅛	.428	.646	.865	1.31	1.75
.27	3¼	.452	.682	.914	1.38	1.85
.28	3⅜	.477	.720	.965	1.46	1.95
.29	3½	.502	.758	1.02	1.53	2.05
.30	3⅝	.527	.796	1.07	1.61	2.16
.31	3¾	.553	.836	1.12	1.69	2.26
.32	3 13/16	.580	.876	1.18	1.77	2.37
.33	3 15/16	.606	.916	1.23	1.86	2.48
.34	4 1/16	.634	.957	1.28	1.94	2.60
.35	4 3/16	.661	.999	1.34	2.02	2.71
.36	4 5/16	.688	1.04	1.40	2.11	2.82
.37	4 7/16	.717	1.08	1.45	2.20	2.94
.38	4 9/16	.745	1.13	1.51	2.28	3.06
.39	4 11/16	.774	1.17	1.57	2.37	3.18
.40	4 13/16	.804	1.21	1.63	2.46	3.30
.41	4 15/16	.833	1.26	1.69	2.55	3.42
.42	5 1/16	.863	1.30	1.75	2.65	3.54
.43	5 3/16	.893	1.35	1.81	2.74	3.67
.44	5¼	.924	1.40	1.88	2.83	3.80
.45	5⅜	.955	1.44	1.94	2.93	3.93
.46	5½	.986	1.49	2.00	3.03	4.05
.47	5⅝	1.02	1.54	2.07	3.12	4.18
.48	5¾	1.05	1.59	2.13	3.22	4.32
.49	5⅞	1.08	1.64	2.20	3.32	4.45
.50	6	1.11	1.68	2.26	3.42	4.58
.51	6⅛	1.15	1.73	2.33	3.52	4.72
.52	6¼	1.18	1.78	2.40	3.62	4.86
.53	6⅜	1.21	1.84	2.46	3.73	4.99
.54	6½	1.25	1.89	2.53	3.83	5.13
.55	6⅝	1.28	1.94	2.60	3.94	5.27
.56	6¾	1.31	1.99	2.67	4.04	5.42
.57	6 13/16	1.35	2.04	2.74	4.15	5.56
.58	6 15/16	1.38	2.09	2.81	4.26	5.70
.59	7 1/16	1.42	2.15	2.88	4.36	5.85
.60	7 3/16	1.45	2.20	2.96	4.47	6.00
.61	7 5/16	1.49	2.25	3.03	4.59	6.14
.62	7 7/16	1.52	2.31	3.10	4.69	6.29

* From Circular No. 36, Utah Agricultural College Experiment Station, by O. W. Israelsen.

TABLE 2 (CONTINUED).—DISCHARGE TABLES FOR RECTANGULAR WEIRS.

Head in Feet	Head in Inches	Discharge in Cubic Feet per Second for Crests of Various Lengths				
		1 Foot	1.5 Feet	2 Feet	3 Feet	4 Feet
.63	7 9/16	1.56	2.36	3.17	4.81	6.44
.64	7 11/16	1.60	2.42	3.25	4.92	6.59
.65	7 13/16	1.63	2.47	3.32	5.03	6.75
.66	7 15/16	1.67	2.53	3.40	5.15	6.90
.67	8 1/16	1.71	2.59	3.47	5.26	7.05
.68	8 3/16	1.74	2.64	3.56	5.38	7.21
.69	8¼	1.78	2.70	3.63	5.49	7.36
.70	8⅜	1.82	2.76	3.71	5.61	7.52
.71	8½	1.86	2.81	3.78	5.73	7.68
.72	8⅝	1.90	2.87	3.86	5.85	7.84
.73	8¾	1.93	2.93	3.94	5.97	8.00
.74	8⅞	1.97	2.99	4.02	6.09	8.17
.75	9	2.01	3.05	4.10	6.21	8.33
.76	9⅛	2.05	3.11	4.18	6.33	8.49
.77	9¼	2.09	3.17	4.26	6.45	8.66
.78	9⅜	2.13	3.23	4.34	6.58	8.82
.79	9½	2.17	3.29	4.42	6.70	8.99
.80	9⅝	2.21	3.35	4.51	6.83	9.16
.81	9¾	2.25	3.41	4.59	6.95	9.33
.82	9 13/16	2.29	3.47	4.67	7.08	9.50
.83	9 15/16	2.33	3.54	4.75	7.21	9.67
.84	10 1/16	2.37	3.60	4.84	7.33	9.84
.85	10 3/16	2.41	3.66	4.92	7.46	10.01
.86	10 5/16	2.46	3.72	5.01	7.59	10.19
.87	10 7/16	2.50	3.79	5.10	7.72	10.36
.88	10 9/16	2.54	3.85	5.18	7.85	10.54
.89	10 11/16	2.58	3.92	5.27	7.99	10.71
.90	10 13/16	2.62	3.98	5.35	8.12	10.89
.91	10 15/16	2.67	4.05	5.44	8.25	11.07
.92	11 1/16	2.71	4.11	5.53	8.38	11.25
.93	11 3/16	2.75	4.18	5.62	8.52	11.43
.94	11¼	2.79	4.24	5.71	8.65	11.61
.95	11⅜	2.84	4.31	5.80	8.79	11.79
.96	11½	2.88	4.37	5.89	8.93	11.98
.97	11⅝	2.93	4.44	5.98	9.06	12.16
.98	11¾	2.97	4.51	6.07	9.20	12.34
.99	11⅞	3.01	4.57	6.15	9.34	12.53
1.00	12	3.06	4.64	6.25	9.48	12.72
1.01	12⅛	....	4.71	6.34	9.62	12.91
1.02	12¼	....	4.78	6.43	9.76	13.10
1.03	12⅜	....	4.85	6.52	9.90	13.28
1.04	12½	....	4.92	6.62	10.04	13.47
1.05	12⅝	....	4.98	6.71	10.18	13.66
1.06	12¾	....	5.05	6.80	10.32	13.85
1.07	12 13/16	....	5.12	6.90	10.46	14.04
1.08	12 15/16	....	5.20	6.99	10.61	14.24
1.09	13 1/16	....	5.26	7.09	10.75	14.43
1.10	13 3/16	....	5.34	7.19	10.90	14.64
1.11	13 5/16	....	5.41	7.28	11.04	14.83

TABLE 2 (CONCLUDED).—DISCHARGE TABLES FOR RECTANGULAR WEIRS.

Head in Feet	Head in Inches	Discharge in Cubic Feet per Second for Crests of Various Lengths				
		1 Foot	1.5 Feet	2 Feet	3 Feet	4 Feet
1.12	13 7/16	....	5.48	7.38	11.19	15.03
1.13	13 9/16	....	5.55	7.47	11.34	15.22
1.14	13 11/16	....	5.62	7.57	11.48	15.42
1.15	13 13/16	....	5.69	7.66	11.64	15.62
1.16	13 15/16	....	5.77	7.76	11.79	15.82
1.17	14 1/16	....	5.84	7.86	11.94	16.02
1.18	14 3/16	....	5.91	7.96	12.09	16.23
1.19	14¼	....	5.98	8.06	12.24	16.43
1.20	14⅜	....	6.06	8.16	12.39	16.63
1.21	14½	....	6.13	8.26	12.54	16.83
1.22	14⅝	....	6.20	8.35	12.69	17.03
1.23	14¾	....	6.28	8.46	12.85	17.25
1.24	14⅞	....	6.35	8.56	12.99	17.45
1.25	15	....	6.43	8.66	13.14	17.65
1.26	15⅛	....	....	....	13.30	17.87
1.27	15¼	....	....	....	13.45	18.07
1.28	15⅜	....	....	....	13.61	18.28
1.29	15½	....	....	....	13.77	18.50
1.30	15⅝	....	....	....	13.93	18.71
1.31	15¾	....	....	....	14.09	18.92
1.32	15 13/16	....	....	....	14.24	19.12
1.33	15 15/16	....	....	....	14.40	19.34
1.34	16 1/16	....	....	....	14.56	19.55
1.35	16 3/16	....	....	....	14.72	19.77
1.36	16 5/16	....	....	....	14.88	19.98
1.37	16 7/16	....	....	....	15.04	20.20
1.38	16 9/16	....	....	....	15.20	20.42
1.39	16 11/16	....	....	....	15.36	20.64
1.40	16 13/16	....	....	....	15.53	20.86
1.41	16 15/16	....	....	....	15.69	21.08
1.42	17 1/16	....	....	....	15.85	21.29
1.43	17 3/16	....	....	....	16.02	21.52
1.44	17¼	....	....	....	16.19	21.74
1.45	17⅜	....	....	....	16.34	21.96
1.46	17½	....	....	....	16.51	22.18
1.47	17⅝	....	....	....	16.68	22.41
1.48	17¾	....	....	....	16.85	22.64
1.49	17⅞	....	....	....	17.01	22.85
1.50	18	....	....	....	17.17	23.08

-TABLE 3.—DISCHARGE TABLES FOR CIPOLLETTI WEIRS.*

Head in Feet	Head in Inches	Discharge in Cubic Feet per Second for Crests of Various Lengths				
		1 Foot	1.5 Feet	2 Feet	3 Feet	4 Feet
0.20	2⅜	0.30	0.45	0.60	0.90	1.20
.21	2½	.32	.48	.64	.97	1.29
.22	2⅝	.35	.52	.69	1.04	1.38
.23	2¾	.37	.55	.74	1.11	1.47
.24	2⅞	.39	.59	.79	1.18	1.57
.25	3	.42	.63	.84	1.25	1.67
.26	3⅛	.45	.67	.89	1.33	1.77
.27	3¼	.47	.70	.94	1.40	1.87
.28	3⅜	.50	.74	.99	1.48	1.97
.29	3½	.53	.79	1.04	1.56	2.08
.30	3⅝	.56	.83	1.10	1.64	2.19
.31	3¾	.59	.87	1.15	1.73	2.30
.32	3 13/16	.61	.91	1.21	1.80	2.41
.33	3 15/16	.64	.95	1.27	1.89	2.52
.34	4 1/16	.67	1.00	1.32	1.98	2.64
.35	4 3/16	.70	1.04	1.38	2.07	2.75
.36	4 5/16	.73	1.09	1.44	2.16	2.87
.37	4 7/16	.77	1.13	1.50	2.25	2.99
.38	4 9/16	.80	1.18	1.57	2.34	3.11
.39	4 11/16	.83	1.23	1.63	2.43	3.24
.40	4 13/16	.87	1.28	1.69	2.53	3.36
.41	4 15/16	.90	1.32	1.76	2.62	3.49
.42	5 1/16	.93	1.37	1.82	2.72	3.61
.43	5 3/16	.97	1.42	1.89	2.81	3.74
.44	5¼	1.00	1.47	1.95	2.91	3.87
.45	5⅜	1.04	1.53	2.02	3.01	4.01
.46	5½	1.07	1.58	2.09	3.11	4.14
.47	5⅝	1.11	1.63	2.16	3.21	4.28
.48	5¾	1.15	1.68	2.23	3.32	4.41
.49	5⅞	1.18	1.74	2.30	3.42	4.55
.50	6	1.22	1.79	2.37	3.53	4.69
.51	6⅛	1.26	1.85	2.44	3.64	4.83
.52	6¼	1.30	1.90	2.51	3.74	4.97
.53	6⅜	1.34	1.96	2.59	3.85	5.12
.54	6½	1.38	2.02	2.66	3.96	5.26
.55	6⅝	1.42	2.07	2.74	4.07	5.41
.56	6¾	1.46	2.13	2.81	4.18	5.56
.57	6 13/16	1.50	2.19	2.89	4.30	5.71
.58	6 15/16	1.54	2.25	2.97	4.41	5.86
.59	7 1/16	1.58	2.31	3.05	4.53	6.01
.60	7 3/16	1.62	2.37	3.13	4.64	6.17
.61	7 5/16	1.67	2.43	3.20	4.76	6.32
.62	7 7/16	1.71	2.49	3.28	4.88	6.47
.63	7 9/16	1.75	2.55	3.37	5.00	6.63
.64	7 11/16	1.80	2.62	3.45	5.12	6.79
.65	7 13/16	1.84	2.68	3.53	5.24	6.95
.66	7 15/16	1.89	2.75	3.61	5.36	7.11
.67	8 1/16	1.93	2.81	3.70	5.48	7.28

*From Circular No. 36, Utah Agricultural College Experiment Station, by O. W. Israelsen.

TABLE 3 (CONTINUED).—DISCHARGE TABLES FOR CIPOLLETTI WEIRS.

Head in Feet	Head in Inches	Discharge in Cubic Feet per Second for Crests of Various Lengths				
		1 Foot	1.5 Feet	2 Feet	3 Feet	4 Feet
.68	8 3/16	1.98	2.87	3.79	5.61	7.44
.69	8¼	2.02	2.94	3.87	5.73	7.61
.70	8⅜	2.07	3.01	3.95	5.86	7.77
.71	8½	2.12	3.07	4.04	5.99	7.94
.72	8⅝	2.16	3.14	4.13	6.12	8.11
.73	8¾	2.21	3.21	4.22	6.24	8.28
.74	8⅞	2.26	3.28	4.31	6.38	8.45
.75	9	2.31	3.35	4.40	6.51	8.62
.76	9⅛	2.36	3.42	4.49	6.64	8.80
.77	9¼	2.41	3.49	4.58	6.77	8.97
.78	9⅜	2.46	3.56	4.67	6.90	9.15
.79	9½	2.51	3.63	4.76	7.04	9.33
.80	9⅝	2.56	3.70	4.85	7.18	9.51
.81	9¾	2.61	3.77	4.95	7.31	9.69
.82	9 13/16	2.66	3.84	5.04	7.45	9.87
.83	9 15/16	2.71	3.92	5.14	7.59	10.05
.84	10 1/16	2.77	3.99	5.23	7.73	10.23
.85	10 3/16	2.82	4.07	5.33	7.87	10.42
.86	10 5/16	2.87	4.14	5.43	8.01	10.60
.87	10 7/16	2.93	4.22	5.52	8.15	10.79
.88	10 9/16	2.98	4.29	5.62	8.30	10.98
.89	10 11/16	3.04	4.37	5.72	8.44	11.17
.90	10 13/16	3.09	4.45	5.82	8.59	11.36
.91	10 15/16	3.15	4.53	5.92	8.73	11.55
.92	11 1/16	3.20	4.60	6.02	8.88	11.74
.93	11 3/16	3.26	4.68	6.13	9.03	11.94
.94	11¼	3.32	4.76	6.23	9.17	12.13
.95	11⅜	3.37	4.84	6.33	9.32	12.33
.96	11½	3.43	4.92	6.44	9.48	12.53
.97	11⅝	3.49	5.00	6.55	9.62	12.72
.98	11¾	3.55	5.09	6.64	9.78	12.92
.99	11⅞	3.61	5.17	6.75	9.93	13.12
1.00	12	3.67	5.25	6.86	10.08	13.32
1.01	12⅛	....	5.33	6.96	10.24	13.53
1.02	12¼	....	5.42	7.07	10.40	13.73
1.03	12⅜	....	5.50	7.18	10.55	13.94
1.04	12½	....	5.59	7.29	10.71	14.15
1.05	12⅝	....	5.67	7.40	10.87	14.35
1.06	12¾	....	5.76	7.51	11.03	14.56
1.07	12 13/16	....	5.84	7.62	11.18	14.76
1.08	12 15/16	....	5.93	7.73	11.35	14.98
1.09	13 1/16	....	6.02	7.84	11.51	15.19
1.10	13 3/16	....	6.11	7.96	11.68	15.41
1.11	13 5/16	....	6.20	8.07	11.84	15.62
1.12	13 7/16	....	6.29	8.18	12.00	15.84
1.13	13 9/16	....	6.37	8.29	12.16	16.04
1.14	13 11/16	....	6.46	8.41	12.33	16.26
1.15	13 13/16	....	6.56	8.53	12.50	16.48
1.16	13 15/16	....	6.65	8.65	12.67	16.70

TABLE 3 (CONCLUDED).—DISCHARGE TABLES FOR CIPOLLETTI WEIRS.

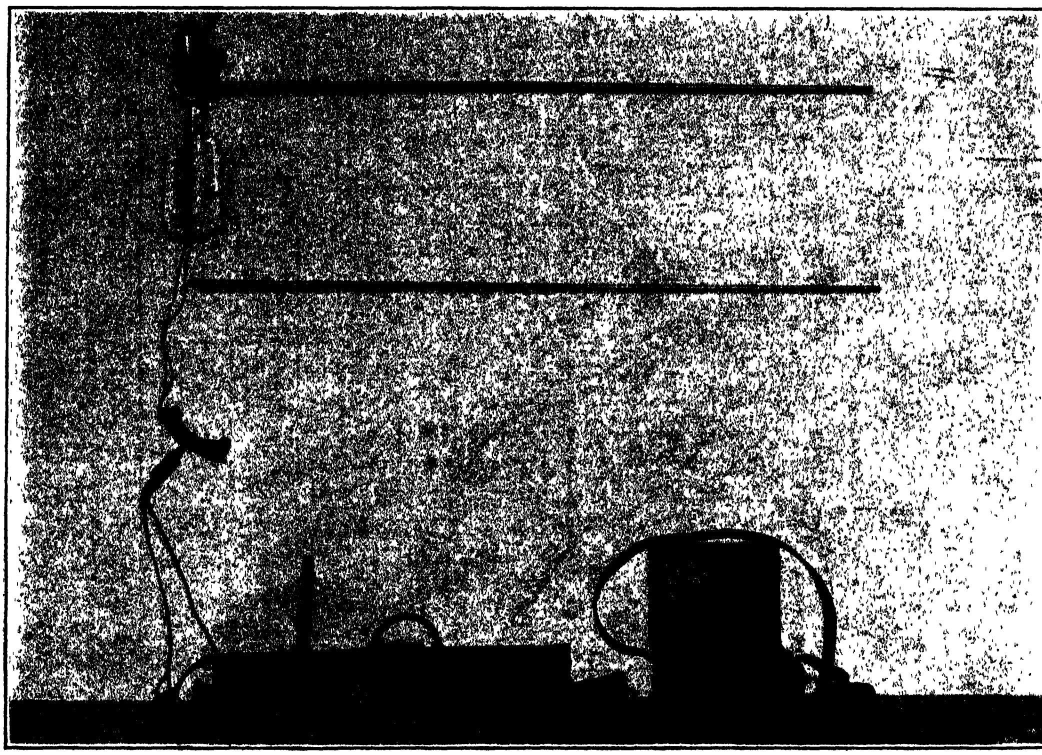
Head in Feet	Head in Inches	Discharge in Cubic Feet per Second for Crests of Various Lengths				
		1 Foot	1.5 Feet	2 Feet	3 Feet	4 Feet
1.17	14 1/16	....	6.74	8.76	12.84	16.93
1.18	14 3/16	....	6.83	8.88	13.01	17.15
1.19	14¼	....	6.93	9.10	13.18	17.37
1.20	14⅜	....	7.02	9.12	13.35	17.59
1.21	14½	....	7.11	9.24	13.52	17.81
1.22	14⅝	....	7.20	9.36	13.69	18.03
1.23	14¾	....	7.30	9.48	13.87	18.27
1.24	14⅞	....	7.40	9.60	14.04	18.49
1.25	15	....	7.49	9.72	14.21	18.71
1.26	15⅛	....	....	....	14.39	18.95
1.27	15¼	....	....	....	14.56	19.17
1.28	15⅜	....	....	....	14.74	19.41
1.29	15½	....	....	....	14.92	19.65
1.30	15⅝	....	....	....	15.11	19.88
1.31	15¾	....	....	....	15.29	20.12
1.32	15 13/16	....	....	....	15.46	20.34
1.33	15 15/16	....	....	....	15.64	20.58
1.34	16 1/16	....	....	....	15.82	20.82
1.35	16 3/16	....	....	....	16.01	21.06
1.36	16 5/16	....	....	....	16.19	21.29
1.37	16 7/16	....	....	....	16.37	21.53
1.38	16 9/16	....	....	....	16.57	21.78
1.39	16 11/16	....	....	....	16.75	22.02
1.40	16 13/16	....	....	....	16.94	22.27
1.41	16 15/16	....	....	....	17.13	22.51
1.42	17 1/16	....	....	....	17.31	22.75
1.43	17 3/16	....	....	....	17.51	23.01
1.44	17¼	....	....	....	17.70	23.26
1.45	17⅜	....	....	....	17.89	23.50
1.46	17½	....	....	....	18.08	23.75
1.47	17⅝	....	....	....	18.28	24.01
1.48	17¾	....	....	....	18.47	24.26
1.49	17⅞	....	....	....	18.66	24.50
1.50	18	....	....	....	18.85	24.75

Current meters are restricted in their use, being expensive, and requiring a more or less skilled operator. They are used in making seepage measurements, and generally where the installation of a weir is not warranted.

A very simple means of measuring the quantity of water flowing in a ditch is by what is known as the "surface float" method. In accuracy this is not to be compared with either the weir or current meter, and I speak of it only as a way out when neither of the others is available.

The principle of the method lies in the fact that area in square feet, times velocity in feet per second, is equal to discharge in cubic feet per second. The method is as follows: Select a uniform section of ditch from 50 to 100 feet long. At two or three points obtain the area, by measuring the depth and the width in several points, and averaging these figures. The width times the average depth

gives the area. Get this area at several points and average them. Say, for example, this is two square feet. The velocity is then obtained by timeing a piece of wood or cane stump over this 50 or 100-foot section. Assume that your watch shows that it took 25 seconds for the chip to travel 100 feet. This shows that the surface velocity is four feet per second. But we have the average area. So we must have the average velocity. Water is always flowing faster on the surface than at lower depths. To obtain the mean velocity it is necessary to apply a certain coefficient. The selection of the constant depends on the area and type of ditch, but for our purpose it is safe to give it a value of 0.65 if it is an earthen ditch and fairly clean, and 0.60 if it is a very weedy earthen ditch, having an area anywhere from 2 to 10 square feet. Thus, if our ditch is clean our velocity becomes $4.0 \times 0.65 = 2.60$ feet per second. The discharge is then $2.6 \times 2 = 5.2$



Small Price rod, current meter, and equipment used in measurement of water.

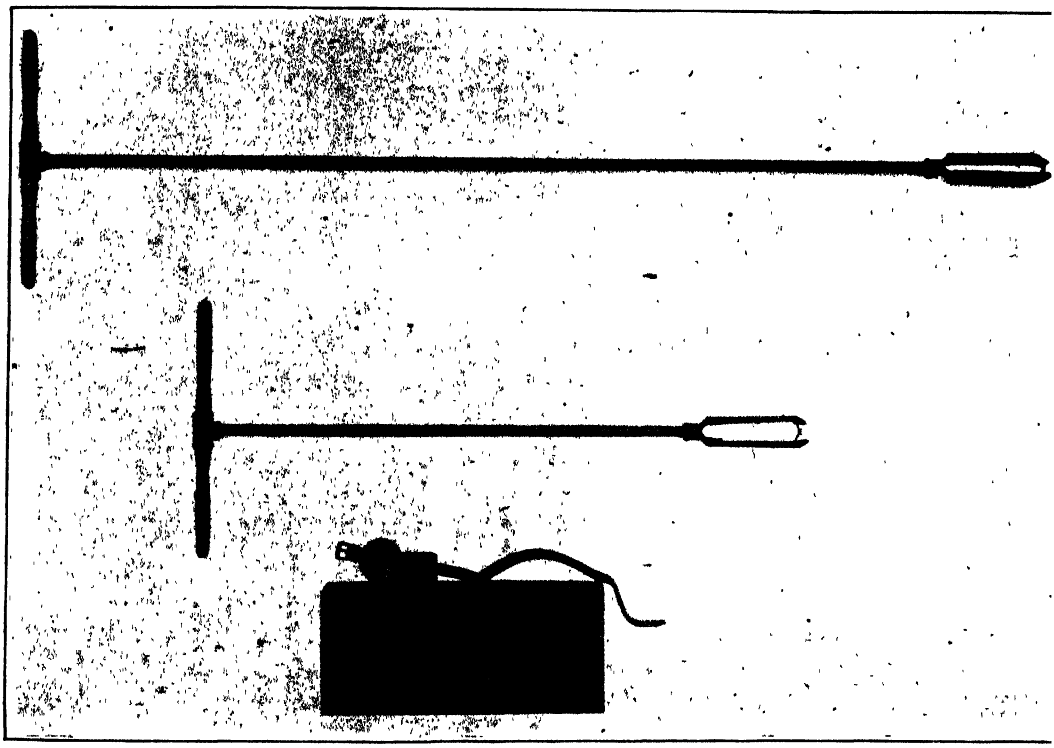
cubic feet per second. Now, remembering that 1 second foot in 24 hours delivers 2 acre feet, we see that our present flow will cover 1 acre 10½ feet deep in 24 hours.

Rating stations consist of a selected section of ditch, whose discharge is known for any depth, generally indicated by a permanent gauge rod. The largest source of error is the changing of the cross-section of the ditch, due to erosion or silt deposits. So in earth ditches it is advisable either to line a section, or to construct a rating flume. This flume should be 12 to 20 feet long (not less than twice the width of the ditch), and about the same width and depth as the ditch itself. The floor should be level (transversally) and should be set to the grade of the ditch; it should be set about 1 to 1½ inches above

the bed of the ditch so that all the silt will be carried through. The flume should be located far enough away from level gates so as to be away from the back-water when the gate is closed. The relation between the depth of water and the corresponding discharge is obtained by actually measuring the flow for different depths in the flume. This is known as rating the flume, and the results are plotted to give the rating curve from which the discharge can be found for any depth.

Once such a flume is rated, which requires more or less experience, the device makes a very simple, efficient means of measuring water.

I hope that this information on measuring devices will be of some value to you. Without a doubt it is a valuable phase of the subject, and I am sure will show you startling results. It is the means of checking up the pumps, locating



Soil-sampling outfit for moisture determination, showing three and six-foot auger, together with air-tight cans for transporting samples from field to laboratory.

serious seepage losses, and of showing you how evenly your water supply is distributed over your plantation. Sandy soils retain less water than loam soils. Are they getting less water or are they getting more where *you* are responsible for the irrigation? Fields when first planted do not require as heavy irrigations as do ratoon fields just starting. How are *you* irrigating your newly-planted fields? A few weirs, rating stations, or even a few casual float measurements will show many things. "The key to the economical use of water," a term much used in California, is measurement.

Soil Moisture and Irrigation.

Mention has been made of the value of soil moisture in tracing losses by

deep percolation. This phase of irrigation studies leads to many other points. For instance, what is the value of a 1-inch rain? If we find from our soil moisture studies, as we have found at Waipio, that it is possible under irrigation to store 1 inch in the upper foot, we see that this rain does no more than wet the surface 10 or 12 inches. This is fine for plant cane, but of little value to ratoon cane, whose roots are farther from the surface. In California they have found that an inch of rain falling on a very dry surface will seldom wet more than 6 inches of soil. A half-inch rain is of no value unless the surface is fairly moist from a preceding rain. This brings out the fact that moisture is carried faster into a moist soil than into a dry soil.

That the soil moisture content can be used as an indication of the time to irrigate has been fairly well proven in California and other western states. The following results have been obtained:

	Minimum Moisture %	Yield
Potatoes	23	292 bu.
	20	308 bu.
	17	176 bu.
Clover	20	17 tons
	17	19.3 tons
	14	19.6 tons

Generally they find that a decreased yield results from keeping a field too wet, or too dry. This, of course, depends to a large extent on the type of soil, age of crop, and other factors. We have found that on our medium soil at Waipio whenever cane looks as if it needed water, the moisture percentage is below 23%. This means that when our moisture percentage gets as low as 25% it is time to irrigate, for we should not wait until the cane is suffering before we apply water, for at such time its growth is checked.

The time to shut off irrigation water before harvesting is a factor that cannot be overlooked. We have recently harvested an experiment at Waipio where irrigation water was withheld 40, 60 and 80 days before harvesting. Juice samples showed that the best juices were obtained where the cane had not been irrigated for 60 days. Where the water had been shut off for 80 days the cane had started to go back, and the juices, though better than where the water had been removed only 40 days, were poorer than the 60-day juices. This is a factor that will, of course, vary with the location, soil type, etc., so we can only say now that this is a point worthy of attention.

An interesting observation was also made this year on the advisability of irrigating as soon as possible after harvesting. One of our fields was irrigated immediately after harvesting with the exception of four or five watercourses. At the end of ten days there was such a marked difference in germination in favor of that which had been irrigated that we were forced to irrigate the remaining portion in order to get the uniform stand necessary for the experiment that had been planned for this field. The observation indicates that a better stand will be obtained by following this practice wherever possible. This

is, of course, subject to conditions. Heavy rains just prior to harvesting may lessen this need.

Does more water produce more cane? This is a question which can only be answered by experiments. We have done some work along this line, but hardly enough to draw any definite conclusions. The opinion based on our data to date, and on the California work that has been done on other crops, is that the yield of cane varies with the water applied to a certain point. Between this point and another point there is a slight increase in yield not sufficient to pay for the excess water, and above this second point there is an actual decrease in the yield due to the excess water.

A great deal of data along this line is available from work done in California on various crops. As a result of five years' experimenting with alfalfa it has been found that the maximum results were obtained with 36 inches of irrigation water. The results are as follows:

Depth of Irrigation.	Yield.
0 irrigation	3.80 tons alfalfa
12" "	5.60 " "
18" "	6.80 " "
24" "	7.90 " "
30" "	9.00 " "
36" "	9.30 " "
48" "	9.00 " "
60" "	8.40 " "

The greatest yield with potatoes was obtained with 60 inches of water, but only 10% greater than the next largest yield obtained with 20 inches of water. The results of this work show that from 18 inches to 20 inches are the water requirement for the maximum yield of potatoes.

Work on sugar beets shows that above 20 inches of water there is only a very slight increase in yield. Duty of water data on barley shows that the greatest yield was obtained with 7.50 inches, and the smallest with 40 inches of water. Oats gave a maximum yield with 20 inches, and with wheat the yield with 15 and 50 inches was practically the same. The sugar beet work also shows that the greatest purity was obtained with the smaller application of water.

Of course, these data all pertain to crops of a different nature than sugar cane, but because the tendencies are so general for all other crops, we are led to suppose that possibly it is true for our crop. The only experiment which we have harvested gave practically identical yields for applications of 2 inches, 6 inches and 9 inches per irrigation. However, the experiment was only preliminary, and not accurate enough to draw conclusions. We can conclude, however, that the subject is of enough interest to look into. If we can produce the same yields of cane with smaller amounts of water we are opening the road for great savings. If we can reduce the time of irrigating 1 minute per line, we would save $12 per acre from the labor end of irrigating alone, to say nothing of the saving in water and pump expense.

Whether or not every other row irrigation is practical is dependent on whether the lateral percolation is sufficient to wet the area where water has not been applied directly. With hilled cane a very practical method of handling trash, and a method possibly to be recommended for this form of irrigating is

to pull the trash into every other row and irrigate in the other line. The trash keeps the surface soil moist, and increases the capillary connection between this line and the lines to which water has been applied. With a heavy soil, where we should expect lateral percolation to be slower than downward percolation, this practice may not prove very successful. Soil samples taken at Waipio show that 2 or 3 days after irrigation the moisture percentage in the furrow that was irrigated, and that which did not receive water, was practically identical.

Sugar Analysis and the Saccharimetric Scale.*

The Association of Official Agricultural Chemists held its annual convention in Washington, D. C., on November 17, 18 and 19. Matters pertaining to sugar occupied an important place on the program and took up the entire forenoon of the first day's session.

Referee Bryan's Report.

Mr. A. Hugh Bryan, referee on sugar, presented his report, divided into five parts. First, in regard to recommendations made by the former referee, Dr. C. A. Browne, he agreed with Browne that further study be given to the modifications proposed in 1916 for determining sucrose by acid and invertase inversion; to methods for the determination of small amounts of reducing sugars in the presence of sucrose; to the optical methods for estimating raffinose in beet products using enzyms for the hydrolysis. These three items he thought should be investigated in the carbohydrate laboratory of the Bureau of Chemistry. He suggested that the methods of determining copper by reduction of the oxide in alcoholic vapors be studied by workers outside of the Bureau.

In regard to matters for study advanced by Dr. W. D. Horne in 1917 the referee concluded that raw sugars might be mixed on a glass plate with a rolling pin or in a mortar with a pestle equally well; that in prescribing a minimum amount of lead in defecation, the regulations mean "just enough lead to cause a clear defecation"; that he personally preferred the average of a number of polariscopic readings to a reading substantiated by readings above and below the main reading; that polarizations of raw cane sugars made at temperatures other than 20° C. be corrected by the formula:

$$P20 = Pt + 0.0015\ (Pt\text{-}80)\ (to\text{-}20)$$

He accepted Horne's suggestions, however, that in case where the invert sugar is known the formula be $P20 = Pt + 0.0003P\ (t\text{-}20)\text{-}0.00812L\ (t\text{-}20)$, where $P =$ polarization and $L =$ levulose ($\frac{1}{2}$ the invert sugar).

In conjunction with the former formula he gave a table of corrections for polarizations from 80 to 97 and for temperatures from 21° to 35° C. He advised against the use of the Beaumé scale.

* Facts About Sugar, Dec. 13, 1919, pp. 470, 471.

The American Polariscope.

In part two the referee discussed the proposed American-made polariscope, advocating the Jellet-Cornu polarizing system as simpler and cheaper, while being sufficiently sensitive for technical work. He discussed the much debated question of the normal weight of sugar to be used in polarizations, indicating a preference for the proposed change to 20 grams. He said a committee had been appointed by the American Chemical Society to get in touch with the various governments abroad with a view to arranging an international standard for the polariscope.

In part three was discussed the reestablishment of the 100° point on the saccharimetric scale by Bates and Jackson of the Bureau of Standards, with the consequent changes in the standard quartz plates tested in that institution. The referee strongly recommended that the corrected values be not employed until their accuracy shall have been agreed to internationally, basing his position on Herzfeld's question of the complete accuracy of the new value and the difficulties which some chemists may have in applying the corrections.

Part four dealt with temperature corrections to be applied in the polarization of cane sugars at temperatures other than 20° C., reference to which has been made above. More than 4000 comparative observations demonstrated the close approximation of the corrected polarizations to the tests made at the standard temperature. A chart of corrections was given covering all ordinary temperatures and polarizations.

Paper by Dr. Browne.

A paper on "The Attitude of the New York Sugar Trade Upon the New U. S. Bureau of Standards Value for Standardizing Saccharimeters," by C. A. Browne of the New York Sugar Trade Laboratory, followed the referee's report. Dr. Browne said:

"The question of the standardization value of normal quartz plates for saccharimeters which Mr. A. H. Bryan discusses in this year's referee's report is a matter of extreme importance, as the difference of 0.1 sugar degrees between the official standards of Berlin and Washington will mean a difference of over $1,000,000 in the valuation of sugars handled by the New York sugar trade. This conflict of opposing standards has already caused some uneasiness in the trade, and the matter has been carefully considered by the directors of the New York Sugar Trade Laboratory, who represent equally the buyers and sellers of raw sugar.

"The standard of graduation for the German or Ventzke scale which has been employed by the New York sugar trade up to the present time is the one which is being used by practically all members of the International Commission for Uniform Methods of Sugar Analysis, the methods of which are the official methods of the New York sugar trade. The directors of the New York Sugar Trade Laboratory, after careful consideration of the question, voted unanimously against the adoption of the new United States Bureau of Standards value for standardizing saccharimeters for the following reasons:

"(1) That this new United States Bureau of Standards value has been criti-

cized by European investigators, and until it has been confirmed by testing bureaus in other countries and has been agreed to internationally, it would be exceedingly unwise to adopt a value which might have to be changed again to something else.

Against Hasty Changes.

"The directors of the New York Sugar Trade Laboratory do not wish to make any departure in methods or standards unless the proposed changes have a fair prospect of permanency, especially in international transactions; otherwise the sugar trade will be continually subjected to disturbances of this kind.

"(2) Granting that there may be a slight error in the present German Standard, and even granting that the new United States Bureau of Standards value may be correct, the directors of the New York Sugar Trade Laboratory are of the opinion that no injustice is being done at present to the sellers of raw sugar for the reason that the minus error, due to scale graduation, is offset by an equal or greater error due to the volume of the lead precipitate in clarification.

"If a scale error exists it should by all means be corrected, and the true standardization value fixed by international agreement. When this scale error is corrected, the counter-balancing lead precipitate error should also be corrected either by dry lead defecation, as proposed by Horne, or by other accurate means.

"I might say in conclusion that this decision of the directors of the New York Sugar Trade Laboratory is in complete agreement with the opinion of Dr. Prinsen Geerligs of Holland and other European authorities."

Bates Discusses Report.

Dr. Frederick J. Bates, director of the Saccharimetric Division of the Bureau of Standards, read a paper comprehensively discussing certain features of the report of the Referee on Sugar. In regard to the Beaumé scale, he agreed that it would be more advantageous if the sugar industries would use the Brix scale, but since the Beaumé scale is so firmly intrenched it must be reckoned with, and in order to afford the most correct scale possible the Bureau had recalculated the scale on the specific gravity determinations of Plato, which are the most scientifically correct, had adopted the modulus 145 and had referred sugar solutions at 20° C. to water at 20° C. This scale he recommended to replace the two different Beaumé scales given in the provisional Methods of Analysis of the Association of Official Agricultural Chemists.

The Normal Weight Question.

Referring to the question of an international normal weight for sugar analysis, he called attention to the long struggle which culminated in doing away with the old German weight of 26.048 grams and the adoption by the International Sugar Commission of the 26-gram normal weight at the same time that 20° C. was adopted as the standard temperature. He showed that all the world but France uses this normal weight, and that France would probably be unwilling to adopt any new weight. He advocated the retention of the present weight,

both on account of the greater inherent accuracy of a large weight and the serious inconvenience that would come from any change.

In reference to the committee appointed by the American Chemical Society to arrange with foreign governments for an international sugar weight of 20 grams, the author wished to make the correction that this committee had merely been appointed to ascertain whether some European nations, particularly England and France, would be willing to adopt a 20-gram normal weight.

OPPOSES REFEREE'S CONCLUSION.

In the matter of standardizing quartz plates by the Bureau of Standards, Bates showed that the difficulties feared by the referee would prove groundless through applying proportional fractions of the 100° point correction when polarizing solutions reading less than 100° S. As to foreign criticisms of the Bureau's redetermined 100° point, Bates stated that the only such criticism the Bureau is aware of is one by Herzfeld, "about 150 words in length, confined to a short discussion of several minor points involved in the preparation of the sugar used by the bureau of standards. Dr. Herzfeld merely conveys the idea of a possibility of the existence of a slight error due to these causes. He does not furnish the slightest proof that any error was made. On the contrary, all measurements and all contributary data developed since the determination of the constant by the Bureau of Standards have merely served to verify the correctness of the new value."

In view of the above he advised against the referee's recommendation that members sending quartz plates to the Bureau of Standards for standardization request that the Bureau certify on the old value of the 100° point, in place of the present corrected value, until this has been adopted internationally.

In the discussion which followed Dr. Bates' paper it was pointed out that the Bureau of Standards' work on the 100° point of the polariscope was conducted with the utmost precaution and the one criticism of it is merely a suggestion that some inversion of the pure sucrose used may have occurred. But no evidence of any such inversion is given, nor is it at all likely, as the sugar solutions used never were heated above 35° C.

The government will doubtless continue to employ the corrective value and it is important that all remaining errors of polarization, especially that elevation due to the volume of the lead precipitate be eliminated as soon as possible.

The following remarks were made by Dr. W. D. Horne, relative to recommendations proposed by Dr. A. Hugh Bryan, Referee on Sugar:

"In mixing sugar samples particular care should be taken to avoid excessive exposure to the air. Speed of work is of first importance; and avoidance of exposing thin layers of sugar may be helped by mixing in a mortar instead of on a plate.

"In cases where the invert sugar is known, more accurate results for individual samples may be obtained by using the formula

$$P20 = Pt. + 0.003P\ (t\text{-}20) - 0.00812L\ (t\text{-}20)$$

where $P =$ polarization and $L =$ levulose ($\frac{1}{2}$ the invert sugar).

"The Beaumé scale is so thoroughly intrenched in the industries that it will continue to be used and must be reckoned with. The Bureau of Standards' new

scale and table is of particular value, having the modulus 145, which is close to the average of those heretofore in use, is a round number, and has already been accepted by the Manufacturers' Association. The reference of sugar solution at 20° C. to water at 20° C. is also a great advantage."

Committee on Beaume Scale.

The chairman, Dr. Trobridge, appointed a committee consisting of W. D. Horne, chairman; Frederick Bates, R. E. Doolittle, Paul Rudnick and E. W. Magruder to report upon the most advisable steps to be taken in regard to the Beaumé scale. This committee submitted the following recommendation:

"That the Beaumé scale of the Bureau of Standards (Modulus 145) Table 31, Circular 44, U. S. Bureau of Standards, be adopted as the official Beaumé scale of the Association and that all Beaumé tables and references thereto which are not in accordance with this scale be eliminated from the methods of the Association; and further, that the Committee on Editing Methods of Analysis be authorized to make such changes in the text of the chapter on Saccharine Products as may be necessary to make this recommendation effective."

The chairman also appointed a committee composed of Frederick J. Bates, chairman; C. A. Browne and F. W. Zerban to consider and report upon the questions of the normal sugar weight and the standardization of quartz plates.

An important contribution on "The Double Polarization Method for the Estimation of Sucrose and the Evaluation of the Clerget Divisor" was presented by Dr. Richard F. Jackson and Miss Clara L. Gillis, both of the Bureau of Standards. This paper, which is a record of a very extensive investigation, will be given later in resumé.

[R. S. N.]

The Deterioration of Sugar.*

A Study of the Factors Causing Inversion—Infection by Bacteria and the Influences of Invertase Secreted by Micro-organisms.

By Nicholas Kopeloff and Lillian Kopeloff.†

The phenomenon of deterioration in sugar is now recognized to be a change from sucrose to invert sugar due to the invertase secreted by micro-organisms. In this connection, there have been the valuable contributions of Browne,[1] Owen[2] and others which have been concerned chiefly with the activities of bacteria. It was our purpose to pursue certain suggestions with regard to the importance of molds in the deterioration of sugar. With this end in view, an exhaustive survey

* Sugar, Nov., 1919, p. 578.

† Bacteriologists, Louisiana Experiment Station.

[1] Jour. Ind. Chem. 10 (1918), p. 178.

[2] La. Bul. 125, 146, 153, 162.

was made of the kinds of molds to be found in different sugars. There were three molds that occurred universally in the sugars examined, belonging to the *Aspergilli* which are frequently found and of wide distribution in soil, vegetable products of all kinds, water, etc. These molds were examined as to their power to deteriorate sugar by inoculating sterile sugars with them and analyzing the latter before and after incubation. It was found that these molds were capable of inducing very serious losses of sucrose in short time, if the conditions for their activity were favorable. However, deterioration also occurred where the moisture conditions were unfavorable. The physical evidence of growth is found in the development of threads of mycelia, and since enzymes were liberated during cellular activity, it is obvious that invertase is secreted in considerable amount. On the other hand, it was puzzling, indeed, to find evidence of enzyme activity where the molds were unable to grow. This led to a closer scrutiny of the inoculating material, which consisted of mold spores, and it was found that the mold spores (which represent a resting or inactive stage in the life history of molds) were capable of producing deterioration without germination. The conclusion was then irresistible and led to the discovery that mold spores contain the enzyme invertase, and that this enzyme was liberated by spores in sufficient quantity to effect deterioration. (A more detailed account may be found in Bulletin 166 of Louisiana Experiment Station.)

The proof that mold spores contained invertase was established as follows: Molds were grown in pure culture in Petri dishes and the spores floated off with water. This spore suspension was heated to 62.5° C. for 30 minutes, which was sufficient to kill the spores and prevent them from germinating, yet not high enough to injure the enzyme. Likewise, this treatment weakened the spore wall and permitted the invertase to diffuse out more readily. The spore suspension was then crushed with sterile sand and the resultant suspension containing a definite number of spores per cc. (which were acurately counted) was used as an inoculum in sugar solutions of 10 and 20 per cent concentration. Inversion was measured after 3 and 24 hours. Spores heated to 100° C. (which killed the enzyme) produced no inversion, proving that the above activity was enzymic in nature. Twenty cc. of the suspension produced twice the inversion that 10 cc. produced in both 10 and 20 per cent sugar solutions, and this, together with other enzyme laws observed, revealed the fact that the spores of these molds contained the enzyme invertase.

However, the fact that inversion was produced by mold spores in 10 and 20 per cent sugar solutions, is hardly sufficient justification for believing that inversion is similarly produced in sugar where the films surrounding the crystals and which support biological activity are so much more highly concentrated. To throw more light on this problem, sugar solutions ranging in concentration from 10 per cent up to saturation (in increments of 10 per cent) were inoculated with mold spores. It was found that at every concentration employed there was inversion, and the maximum invertase activity of these mold spores occurred between 50 and 60 per cent. This might explain some hitherto inexplicable cases of deterioration in solutions of such high concentration that they might have been assumed to be proof against deterioration. It was very interesting, also, to note in this connection that an increase in the number of spores at any

single concentration was responsible for increased inversion. This raised the query: how many mold spores are needed to produce inversion, at the saturation point, for example? It was found that the least number of spores of the most active mold *Aspergillus* Sydowi Bainier which were required was 5000 per gm. With the other two molds, *Aspergillus niger* and *Penicillium expansum,* between 50,000 and 110,000 spores per gm. were needed to accomplish the same results. Thus the evidence that mold spores alone are capable of deteriorating cane sugar was amply corroborated by the above data.

The significance of this phenomenon is worthy of serious attention since it must needs modify the prevailing conceptions regarding the deterioration of sugar. In other words, if a sugar is badly infected (and that implies the liberation of a considerable quantity of invertase from the spores), then this invertase will induce deterioration regardless of whether the moisture content which was hitherto believed to be the determining factor, is high or low. We have here a new and independent factor to consider in sugar deterioration, namely, the magnitude of the infection. This must be taken in conjunction with the other factor, moisture content, or more strictly speaking, moisture ratio.

That is to say, it has already been pointed out in the important researches of Browne[3] and Owen[4] that the important feature about a sugar is the relation between the moisture and the solids non-sucrose; that is

$$\frac{\text{Moisture}}{100 - \text{Polarization}} = \text{moisture ratio or factor of safety.}$$

This ratio should be less than 0.30 for a Cuban raw sugar to be regarded as safe from deterioration. To illustrate, let us suppose a 96° sugar has 1.14 per cent moisture. Its moisture ratio will be 0.28, and such a sugar will not be expected to deteriorate. On the other hand, a 96° sugar containing 1.36 per cent moisture will have a moisture ratio of 0.34 and will undoubtedly deteriorate on storage.

This empirical fact has received ample substantiation in the laboratory as well as in the field. Therefore it became necessary to investigate the influence of moisture ratio or factor of safety on deterioration by molds. In order to maintain an accurate control a series of laboratory sugars of definite moisture ratios were made by coating large "confectioner's crystals" of refined sugar with blackstrap molasses and sugar syrup (60° Brix) in varying proportions and purging in the centrifugal so that the sugars varied in moisture ratio from 0.08 to 0.20, while the liquid used to coat the crystals, which was inoculated separately in each case, varied in moisture ratio from 0.44 to 0.63. The sugars and molasses were analyzed before and after an incubation period of 4 months and the following conclusions noted:

A decrease in concentration of molasses was responsible for a progressive increase in deterioration where the inoculation of mold spores was appreciable. A decrease in concentration of films of laboratory-made sugars similarly inoculated caused an increase in deterioration after one and four months' incubation periods. This was obtained with moisture ratios less than 0.20 and *a priori* would be contradictory to the factor of safety rule heretofore mentioned, for it will be remembered that it was stated that sugars having moisture ratios

[3] Loc. cit.
[4] Loc. cit.

below 0.30 would not be expected to deteriorate. The explanation for this phenomenon will be discussed in another connection. Suffice it to say that this work with sugars and molasses corroborates the generalizations arrived at in the experiments with sugar solutions where deterioration was found to occur at high concentrations.

In the above work there was likewise evidence that an increase in inoculum was responsible for an increase in deterioration at any given concentration. This paved the way for a more exhaustive study which was concerned with the effect of the amount of inoculum and concentration on the deterioration of sugar by molds. In other words, there are two variable factors operating simultaneously in sugar deterioration, each of which has received attention more or less independently of the other, namely, moisture ratio and infection; but it was our purpose to vary them concomitantly. With this end in view, a series of laboratory sugars was prepared, as outlined above, having moisture ratios varying from 0.14 to 0.24. Each concentration was inoculated with mold spores at the rate of 100, 1,000, 10,000 and 100,000 per gm. respectively, and incubated for 1 and 5½ months periods. The results showed that an increase in inoculum was responsible for an increase in deterioration at any definite concentration, while, on the other hand, an increase in concentration with a definite inoculum was responsible for an increase in deterioration. And it became possible, therefore, to prepare a chart which would indicate whether deterioration would occur or not at any definite moisture ratio, providing the degree of infection were known. For example, 100 spores in a sugar with a moisture ratio of 0.16 produced no deterioration, but did produce deterioration in sugars having moisture ratios greater than 0.17. Again, 1000 spores per gm. failed to produce deterioration at a moisture ratio of 0.08, but did effect deterioration at 0.14. On the other hand, any sugar (within the limits noted) having an infection of 100,000 spores per gm. gave evidence of deterioration.

Next to an elimination of deterioration altogether, the most important commercial consideration is to predict the keeping quality of a sugar. From the standpoint of mold infection this may be done satisfactorily on the basis of the above data. In effect, this is equivalent to saying that if the polarization, moisture content and number of molds per gm. are known, it is possible to predict with a fair degree of confidence what deterioration, if any, will occur. Thus it becomes possible in a practical way to know whether or not certain cargoes of sugar may be kept and which must be used immediately, and in this way a serious economic loss may be avoided.

Finally, it becomes necessary to complete this phase of the problem by considering the importance of bacterial infection in deterioration. This has been done in an experiment just completed, in which 200-lb. bags of Cuban raw sugars were kept under normal storage conditions in the warehouse of the largest sugar factory in this country, and analyzed periodically both chemically and bacteriologically. The data need not be discussed in detail at this point, and it will be sufficient to note that it agrees very closely with the previous work mentioned where molds were employed. In other words, deterioration is the resultant of the two factors working simultaneously, moisture ratio and infection, and upon this basis it becomes possible to predict the keeping quality of sugars and thereby prevent economic losses.

[R. S. N.]

The Fuel Value of Alcohol.*

A Summary and Digest of Investigations Carried Out by the British Government —Importance of Suggestions to Sugar Men—Molasses Becomes More Valuable by Distillation into Power Alcohol.

By Dr. Walter Baunard.

With the contemplated increase in sugar production throughout the world, the question of utilizing the enormous quantities of molasses obtained as a by-product becomes of paramount importance. Especially is this the case in the West Indies, where considerable damage has been inflicted by the enforcement of prohibition in the United States, cutting off a large and ready market for rum and other distilled liquors, manufactured from molasses.

Hawaiian sugar planters and also planters in the Philippines have studied the alcohol production problem with considerable interest and have achieved some very encouraging results. It is, therefore, particularly timely at this period of stimulated cane sugar production, to examine the salient features of a comprehensive report of the British "Inter-department Committee" on the progress in Great Britain and British colonies, in the development of power alcohol.

In the British Empire there are vast existing and prospective sources of alcohol in the vegetable world, although in the United Kingdom itself production from these sources is now and is likely to remain small, but synthetic production in this country in considerable quantities, especially from coal and coke-oven gases, is promising.

As the price of alcohol for power and traction purposes, to which the name of "power alcohol" may be given, must be such as to enable it to compete with petrol, it is essential that all restrictions concerning its manufacture, storage, transport and distribution should be removed, so far as possible, consistent with safeguarding the revenue and preventing improper use, and that cheap denaturing should be facilitated.

The committee recommends that an organization should be established by the Government to initiate and supervise experimental and practical development work, at home and overseas, on the production and utilization of power alcohol and to report from time to time for public information on all scientific, technical and economic problems connected therewith. This organization should be permanent, have at its disposal the funds necessary for its investigations, be in close relation with the various governments of the Empire, and be so constituted as to be able to deal with alcohol in conjunction with other fuels which are or may become available as a source of power. * * *

The outstanding and fundamental attraction of alcohol motor-fuel as a substitute for any fuel necessary derived from coal or oil deposits lies in the fact that, on account of its chief sources being found in the vegetable world, supplies

*Sugar, Nov., 1919, p. 599 (abbreviated).

of raw material for its manufacture are being continuously renewed and are susceptible of great expansion without encroachment upon food supplies.

"We are of opinion," says the report, "that steps should be taken to insure increased production of power alcohol by the extended use of the vegetable matters from which it may be obtained. Important materials of this nature are: (1) Sugar-containing products, such as molasses, mahua flowers, sugar beet and mangolds; (2) starch or inulin-containing products, such as maize and other cereals, potatoes and artichokes, and (3) cellulose-containing products, such as peat, sulphite wood pulp lyes and wood.

"We have been unable to obtain comprehensive estimates of the world's production of molasses, although we have been furnished with statistics concerning the total quantities shipped from various countries, but there is evidence that large quantities produced in numerous sugar-growing areas are allowed to run to waste. * * *

"We are of opinion that, so far as vegetable sources of raw material for the manufacture of power alcohol are concerned, we must rely mainly, if indeed not entirely, on increased production in tropical and sub-tropical countries.

Denaturants and Denaturing.

"We have received a valuable report from the Government Chemist, Sir James J. Dobbie, upon practices usual in all countries to effect the denaturing of alcohol so that it shall be unfit for human consumption.

"We are of opinion that, when denaturing operations are carried out at any transport depot or yard, the existing regulations of the Board of Customs and Excise should be relaxed to permit the necessary volumetric mixings to be made in any suitable tank or other storage vessel, notwithstanding the fact that such vessel may still contain power alcohol previously denatured, provided that no refilling supplies for vehicles are drawn during the operations nor until after the new mixing is completed to the satisfaction of any officer of the Board in attendance.

"We recommend that, having regard to the exemption of home-produced benzol and shale motor-spirit from the motor-spirit tax (excise) power alcohol when produced in the United Kingdom be correspondingly exempted and that, having regard to the scope for earlier large production in the Empire overseas, importation of power alcohol be permitted free of duty.

"All sales and deliveries of power alcohol should be made on the basis of a certified percentage by volume of absolute ethyl alcohol, with a minimum of 90 per cent at a temperature of 62 degrees F.

"We are of the opinion that in denatured alcohol, or in admixtures of alcohol, benzol, ether, petrol, or the like, sold as power alcohol, the ratio of water to alcohol after admixture should not exceed one part by volume of water to nine parts by volume of alcohol measured at ordinary temperatures.

"We further consider that when benzol, ether, petrol, or the like, are mixed with alcohol in quantities in excess of those which may be legally required as partial denaturants the nature and amounts per cent by volume of such components should be plainly stated on the containers of such mixtures and on the contracts, sales notes, and invoices dealing therewith.

STATE ACTION TO DEVELOP PRODUCTION.

"We have, in a preceding paragraph, referred to the basic difference between alcohol on the one hand, and benzol, petrol, or other petroleum products on the other—a difference which has not as yet been properly appreciated—i. e., the fact that the chief raw materials for the production of the former can be renewed and are susceptible of great expansion, whilst those from which the latter are derived are limited to deposits, definite in extent, that cannot be renewed. Furthermore, as power alcohol is miscible with water in all proportions, its use affords greater safety from fire than does the employment of benzol, petrol or other petroleum products. We consider that these two factors should be regarded as sufficient grounds in themselves to justify State action in fostering the production and utilization of alcohol for power purposes.

"The work of the sections, so far as it has been carried, has been sufficient to show the complex and far-reaching character of the problem, and has convinced us that it can only be handled adequately by concerted Government action.

"We think that the development of the alcohol industry cannot be left entirely to the chances of private enterprise, individual research and the ordinary play of economic forces. No doubt in the long run, after a tedious process of trial and error, alcohol would find its proper place as a power fuel, but only with the maximum of friction, great fluctuations in price and serious waste of time, money and energy. The situation needs to be watched continuously and measures taken from time to time to ensure a smooth and rapid adjustment of supply to demand."

[R S. N.]

The Relation of Forestry to Agriculture.*

By WM. HILLEBRAND.

[In July, 1856, Dr. Wm. Hillebrand delivered the annual address before the Royal Hawaiian Agricultural Society on the subject of forestry, its significance to agriculture, and the importance of protecting the Hawaiian watershed forests. It is truly remarkable that this paper of Dr. Hillebrand's, prepared sixty-four years ago, is so highly pertinent to the forestry situation as it exists today in these Islands. In 1856 he explained the value of forests, the need of protecting them, and the wisdom of strengthening the native forests with introduced species. He told the whole story of the forestry question in such an able and interesting way that we are reprinting his address for the benefit of the readers of the Record.]

It has been customary at the anniversary meetings of our Society hitherto, to pronounce an unremitting eulogy on the calling which unites us here, and from which our Society has borrowed its name. Permit me, for once, to strike

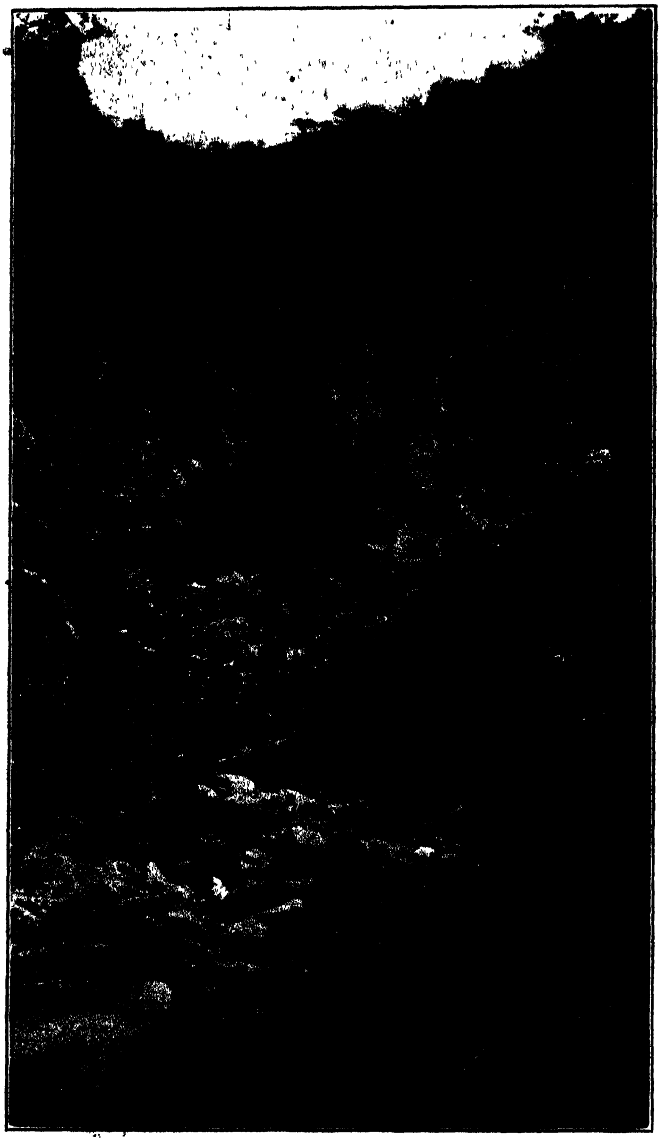
* Extract from Transactions of the Royal Hawaiian Agricultural Society at its Sixth Annual Meeting, July, 1856.

in a different line and to abuse it. To abuse it? I hear you say: but then you are out of place! You ought not to have appeared here! Allow me to correct myself by saying, to abuse its *abuse*—to restrain it within its proper limits.

What is the object of agriculture? Why, to feed and clothe man; to still his hunger and thirst; to protect him from cold and heat, from rain and wind. To supply his wants, and procure his ease, this self-styled lord of creation goes to work without hesitation or scruple to remodel the features of nature, which an all-loving Providence has arranged so as to offer the means of existence to every one of its created beings, from the humblest moss and insect upwards to the highest developed animal. As if there were nothing worth existing beside him, he exterminates what does not administer to his wants or gratify his senses. Noble forests fall groaning under the relentless ax of the pioneer; myriads of modest little plants and weeds disappear under the burrowing edge of the ploughshare, to be replaced by a few kinds of social grasses called cereals, and some other plants and trees, from which he is accustomed to draw his sustenance. The aurox and buffalo, the elk and dam retreat to make room for the cow, the horse and sheep. So fully is he impressed with the propriety of his doings, that even his language outlaws by the opprobrious epithets of weed and vermin whatever poor being, with its innate instinct of self-preservation, interferes with the accomplishment of his preconceived mission. Where before forest and glade, swamp, meadow, lake, heath and river alternated in charming variety, now appears the level monotony of waving corn-fields or uniform pasture ground. Swamps are dried, lakes drained, rivers narrowed to their beds; the noble forest only finds a refuge on the inaccessible mountains, and with them flee away from the settlements of man, or disappear under his tramp, the lily of the fields, the merry songster of the woods. It hardly appears credible, and yet is true, that through the vast extent of China proper, save a few aquatic plants, not one herb is found indigenous to the country, unless cultivated by man. Such is the result of a few thousand years of continuous tillage of the soil. Presently call into operation one of those great political revolutions which sweep an industrious nation from the surface of the earth, or replace it by a barbarous one, the soil will cease to yield its harvests of corn, the rice-fields will dry, not to be replaced by the ancient forest, but to make room for the steppe, the desert. Let us follow up this reflection more in detail.

Once Centers of Civilization; Now Desert.

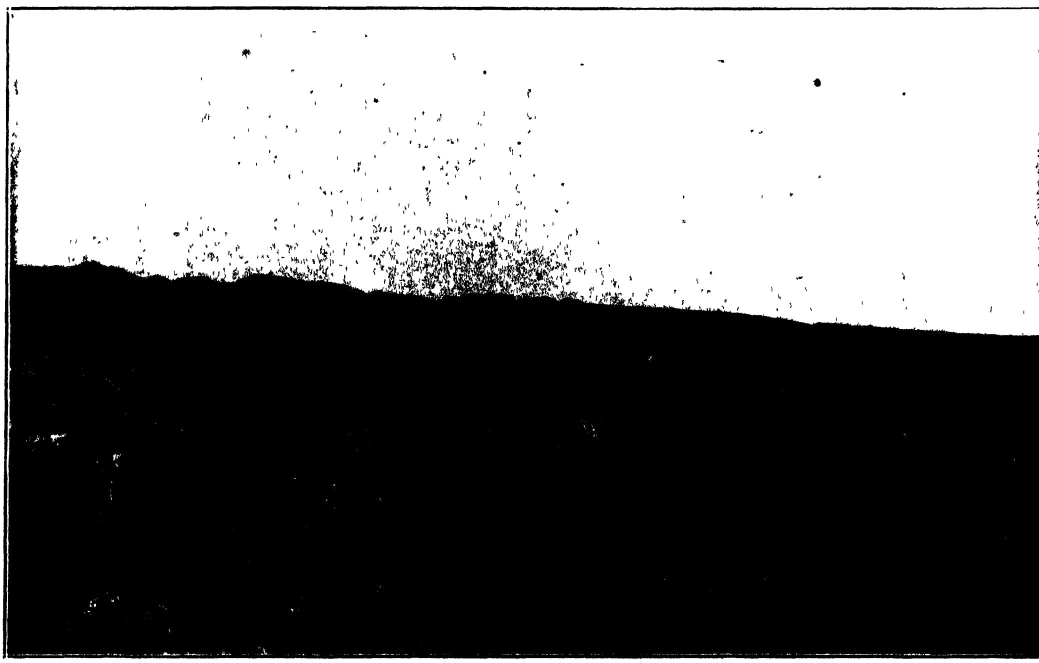
Setting aside the vexed question of the cradle of mankind, leaving it unsettled whether a paradise was on the table-land of Armenia, in the lovely vale of Kashmere, or near the terminus of the two mighty rivers of Central Asia, there can be no question that the first migrations of men took place towards the bottom land, between and around the Euphrates and Tigris, and along the shores of the Caspian Sea. There we see, at the earliest dawn of history, mighty empires flourish—not blooming into existence, but having already passed over that maturity of national development, where the rough virtues of the founders are softened into the refined enjoyment of life, under whose stimulus arts and sciences spring into existence. We actually find them in the last stage of degeneracy, where refinement dissolves itself into voluptuousness, and the effeminacy



Where the ridges of the Koolau Mountains have been protected from cattle an excellent forest cover exists. Photographed December, 1919.

of manners indicates the impending dissolution of the body politic. A succession of four great empires, one taking the place of the other, passes before our astonished eyes before even authenticated history begins; and yet the wondrous monuments, extracted by modern searchers from the bosom of the earth, lift from them the veil of myth, and divest doubt of its support. To this centre points the tradition of the Vedas, the Holy Writ of the Jews, and all historical evidence of the Caucasian tribes, as their origin. From there the man of Ur came with his flocks to settle, by the Lord's command, in Canaan; from there emerged the Pelasgi and Hellenes, destined to shed a never-dying lustre over the land of their choice; and later the Goths, Huns, Mongols; and last, the Turks, to crush the decaying empires of the west, either to invigorate their dying civil-

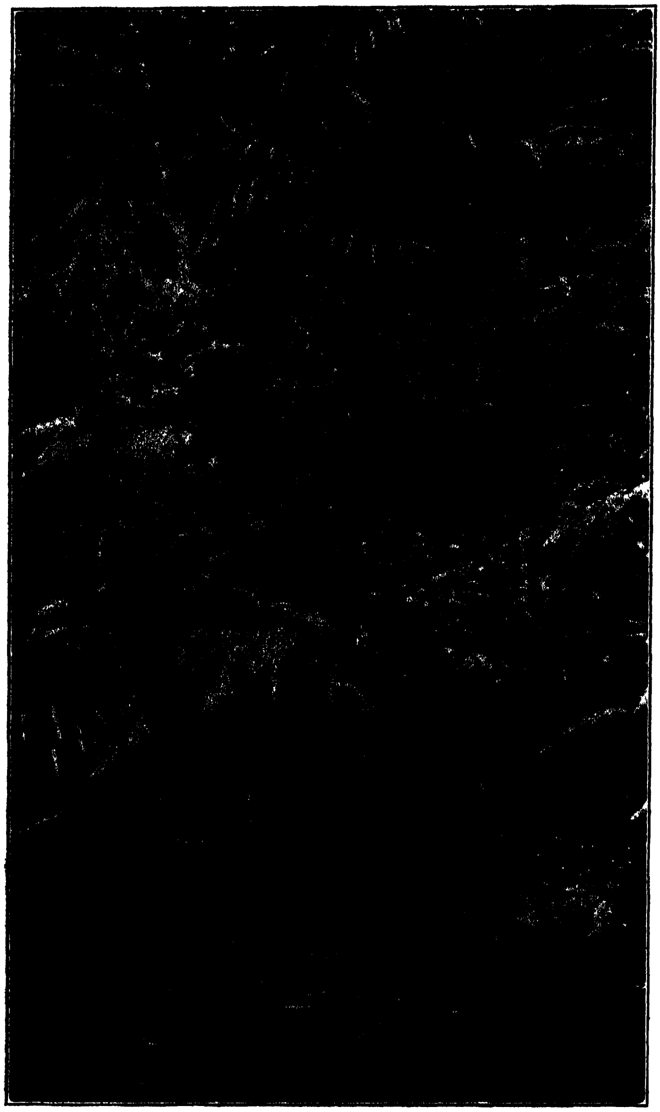
ization by a new stock, or to exterminate it. With them traveled their inseparable companions, the cereals, wheat and barley, already known and cultivated in Greece at the time of Homer—rye and oats completing their migration at a later time. In vain do botanists now search for the original home of those useful plants, disseminated though they are over the whole expanse of the globe, while all historical records trace back their origin to the starting point of man's migration. From where came the grape, which already tempted Noah's weakness; the fig, date and olive, intimately associated with patriarchal life; the peach, apricot and melon? The cherry, which first paraded in Lucullus's triumphal entry in Rome? The lemon, orange, mulberry, and many other of the



"It cannot be denied that in many places the domain of forest has been seriously encroached upon by man, and more by cattle."—Hillebrand, July, 1856.

A view in the Koolau Mountains, showing ridges denuded by cattle. Photographed December, 1919.

precious gifts of a bountiful Providence, which delight the senses of mortals? All testimony coincides that these countries were amongst the most favored of Nature's creation, swelling under exuberant prolificness. From the remotest times of antiquity man felt attracted towards these regions, and generation followed upon generation, populous cities were destroyed, to be superseded by others more splendid. As late as the time of Alexander, the great conqueror's historian tells us of the country between the Tigris and Euphrates, that "its soil is so rich and fecund, that they say the cattle must be driven off from time to time, lest they perish from surfeit." Compare with this the reports of recent travelers, who in these very regions have to wend their toilsome way over dreary deserts for weeks together, and in what few spots they find the country looking green and blooming on both sides of the river, have to limit it by the addition, that the fertility extends only a few miles inland, but beyond all is a sandy

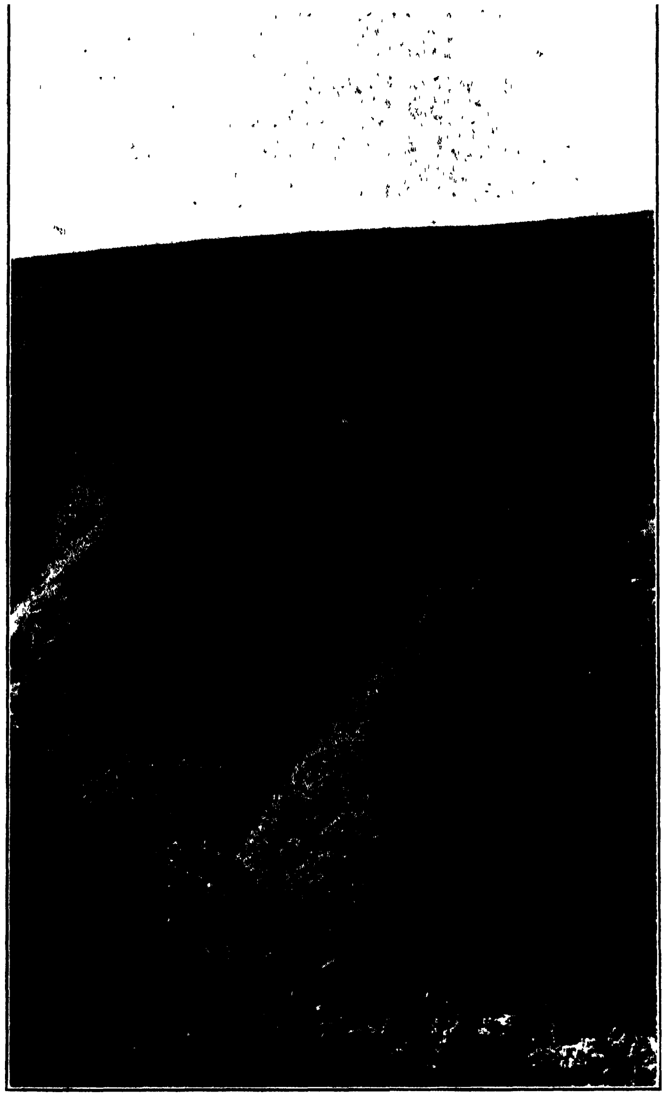


A steep slope protected and well covered.

desert. "Most striking in this part of Mesopotamia," says Ida Pfeiffer, "is the entire want of trees; for the last five days I have not seen one, and I believe there must be many people who have never seen any in their lives. There were tracts of twenty or thirty miles where there was not so much as a shrub, though there is no want of (running) water, for no day passed in which we did not cross one or two rivers, large or small." These remarks refer to the cities of the old Assyrian and Babylonian empires. A few degrees farther east the forty marble columns, time out-lasting monuments of the royal city of Persepolis, loom as melancholy land-marks, at the foot of bleak hills, out of a dreary desert. Not more than one-tenth of the whole area of Persia is at present available for cultivation; the rest consists of sand and bare rocks.

THE LAND OF MILK AND HONEY IS NO MORE.

Turn your eyes to the west—Palestine is no more the land of Canaan, which



A steep slope, denuded by cattle. Photographed December, 1919.

flowed with milk and honey; the physiognomy of neighboring Arabia seems to have extended over its eastern half. The waters of Merom make room for rice-fields during three-fourths of the year; and the Jordan, the only river of Palestine whose waters flow during the whole year, leaves a dry bed in summer between Merom and Chinnereth, and near the Dead Sea, at the terminus of its course, its depth sinks to three feet. The cedars of Lebanon are thinned; the site of Jericho, the City of Palms, is now occupied by the movable tent of the wandering Bedouin, palms and ruins are missing. Mount Carmel alone, with its thickly-wooded slopes and densely-covered valleys, in which myriads of limpid brooks rill through a luxuriant verdure, seems to redeem the old renown of the Promised Land; while the plain of Sharon and the hilly country of Samaria only clothe themselves during the few rainy months in their former splendor. It is not Moslem indolence alone that has to account for these changes. To finish the picture with the poetical words of the illustrious Schleiden: "No Pythagoras in Egypt need

now forbid his disciples the use of the lotus bean; for the soil has lost the power of producing it. The wine of Mendes and Mareotis, which cheered the guests of Cleopatra, and was found worthy the praise of Horace—it has ceased to grow. The assassin will no longer find concealment in the sacred pine forest of Poseidon, to lay in wait for the bard that hurries to the Olympian games, for the pinia has long ago fled from the approaching climate of the desert to the heights of the Arcadian peaks. Where are now the pastures, where the fields around the sacred mansion of Dardanus, which, along the foot of moisture-dripping Mount Ida, fed three thousand mares? Who would not speak of a Xanthus impelling its waves? Who would realize a horse-feeding Argos?"

One simple observation is significant. The clover, which requires a moist climate for its cultivation, has gradually receded from Greece to Italy, and from there to Southern Germany, where already now it begins to be sensibly affected by the increasing drought of summer. Perhaps another singular fact may find its explanation here: Asia, the greatest continent, has a lesser number of indigenous species of plants than Europe.

Germany Eighteen Hundred Years Ago and Now.

Let us look at the other side of the picture. Eighteen hundred years ago my goodly fatherland, Germany, received hard names from Tacitus: *Terra in universum aut silvis horrida, aut paludibus foeda, frugiferarum arborum impatiens*: a country either bristling with dark forests or infected by ugly morasses; swampy on one end and stormy on the other. No fruit trees, he tells us, could grow there. The great rivers Rhine and Danube were every winter covered with so solid a crust of ice, that the barbarians would make their predatory inroads in neighboring districts by passing over them with their cavalry, wagons and material. The elk and reindeer, now confined to the Polar regions, as we learn by Caesar, swarmed over the vast extent of the Hercynian forest. All descriptions of those times would convey the impression, as if it had been a country fit to be inhabited only by brutes and savages, who lived on acorns and would get drunk on barley meal. The parts of Germany with which the Romans at that time had become best acquainted, were the regions along the borders of the Rhine and Danube.

Now place yourself in imagination, on a sunny May day, upon the hill of Schloss Johannisberg, and let your eyes pass slowly in a circle around you. Is that the same country described by the Roman? Is this the sun that shone on his nation's legions? A checkered cloth of vineyard, corn-field and orchard seems to be spread over the undulating plain, only to be interrupted by handsome villages, flourishing cities, and the parks of the wealthy filled with exotic plants. Take a jaunt over the Bergstrasse, along the foot of the Odenwald; for some sixty English miles you walk through a forest—not of sombre oak and pine, but of fruit trees of every description, the scent of whose blossoms pervades the air with fragrance and fills the heart with delight. In summer shiploads of cherries float down the river; and during the vintage, in the fall of the year, the whole population abandons its habitual occupation to cull grapes and press them in vats, amidst a never-ending frenzy of mirth and gaiety. This is the country where neither cherry nor grape would ripen in Tacitus's time. Good

wine is now made in Germany as far north as fifty-one degrees. As late as the time of Strabo it was thought that the grape would not ripen north of the Cevennes. At the present day the finest peaches are raised at Montreuil, near Paris, and France is considered the greatest wine-producing country of the world.

The Revolution Caused by Civilization.

I have tried to delineate in a few general sketches the two phases of the revolution which civilization—for this I take to be equivalent with agriculture—produces on the surface of the globe. In the first an almost uninhabitable country, the perennial mists of which hardly allowed the sun's rays to touch the ground, has been converted into a lovely garden; in the second, the happiest regions of the earth have been transformed into sunburnt deserts. If we ask for the immediate cause of these changes, we are, besides a few accessory agencies, led to the disappearance of the original perennial vegetation, and more especially the trees. Wherever the hardy pioneer fixes his fireplace, his first work is to lay the ax on the noble king of the forest. He chooses woodland in preference, unless rich alluvial bottom land be at hand, because the organic decay which has gone on for centuries under its shadowy roof, has enriched the soil with humus, has mellowed the stiff clay, or rendered more compact the light sand. What then is the effect of forests upon soil, upon climate and vegetation?

The Two Evils Following Waste of Forest.

As long ago as 1804, Alex. Von Humboldt in his "Voyage aux Regions Equinoctioux," warned that the waste of forests entailed two evils on the following generation: a want of fuel, and a deficiency of water. The reality of the first is self-evident; the second, although perhaps vaguely felt by any general observer of Nature, was first by him enunciated dogmatically. Of course, a statement which, if substantiated, entailed such important consequences, was well worthy to arouse a general attention; and since it was first promulgated up to this time, such a mass of evidence has been accumulated that the theory may well be said to have become converted into a doctrine.

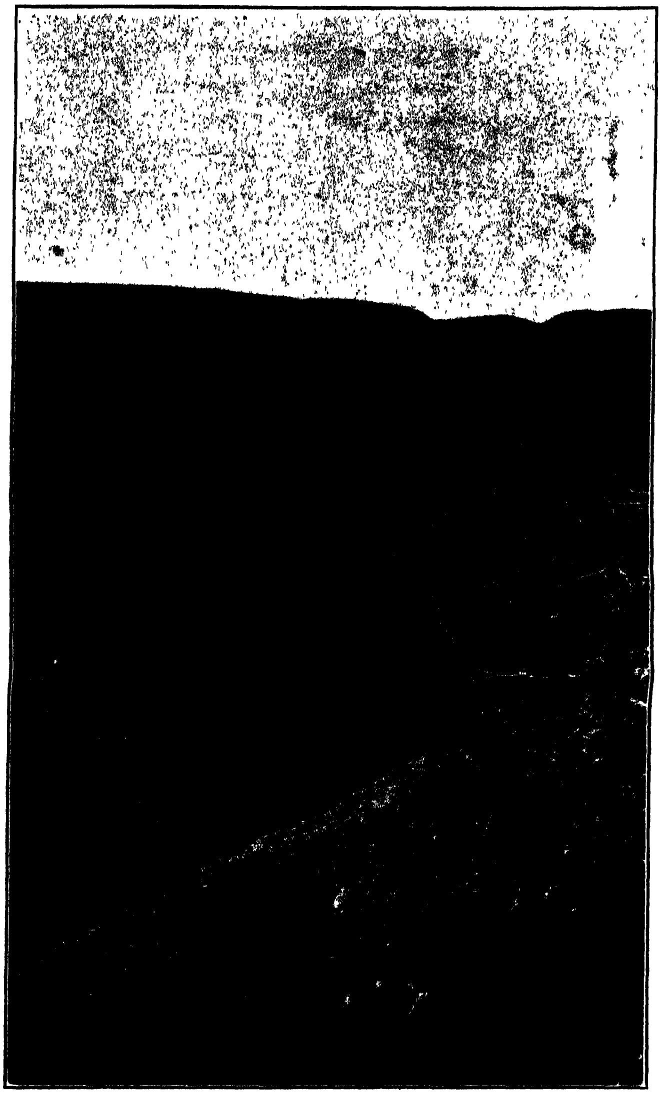
Relation of Forests to Water Supply.

The necessary supply of water to a country is furnished by rivers and rain; or, more generally speaking, by atmospheric deposit. A falling off in the supply by the former source can take place without a corresponding diminution of the latter, although a decrease of rain will always be followed by a scarcity of running water. Springs and sources originate on the same principle upon which artesian wells are constructed. The water, precipitated from the atmosphere as rain, dew, etc., is taken up by the upper permeable layers of the soil, filters through them, follows rents or fissures in the rocks until a solid rock or stiff layer of loam oppose its further progress, and oblige it to follow the declivities of the same; passing by lateral fissures, or heaved up by the pressure of the following waters, it reaches the surface as spring or source. Supposing a sufficient quantity of rain to fall, the amount of running water may still be affected by two causes: a quick evaporation on the surface, or

undue hardness and resistance of the soil. How from a surface exposed openly to the unmitigated rays of the sun, a great waste of deposited moisture should take place by evaporation, needs no further commentary; nor will any one who takes a look at the bleak slopes of the steep basaltic hills back of our village, find difficulty to conceive how a heavy dashing rain will wash away the minutest particle of soil, as soon as it forms from the disintegration of the rock. In the same manner the light, movable humus soil, left after the clearing of a forest, will, when situated on a declivity, be swept away as soon as the firm interlacing network of roots and rootlets has lost its vitality, and no leafy roof moderates the force of the dashing torrent. In both instances an impermeable stratum remains on or near the surface, and the watery deposit, when small, will return to the atmosphere by evaporation; or when large, sweep down in torrents, overfill the beds of rivers, and pervert, by sudden inundations, into a curse what ought to be a blessing to man. A forest will not only, by its cool shade, lessen greatly the evaporation and retain what evaporates under its vault, but its canopy will also moderate the impetus of the falling drops and distribute its descent over a longer space of time. Besides, the humus layer forming its floor, by virtue of its great hygroscopic capacity, retains for a long time the imbibed liquid, and thereby regulates the flow of the rivers, preventing their sudden overflowing and yielding them food long after the rain has ceased. The inundations, of late so frequent, of the river Oder, in its lower course, are attributed by experts to the waste of forests in the mining districts of Upper Silisia, while it is stated that the planting with trees of the formerly naked slopes of the French Alps has done away with the torrential floods which formerly devastated the lower valleys. With regard to the obstacles offered by a thick forest to evaporation, a traveler in South America says: "In the forests the humidity is constant; it exists long after the rainy season has passed; and the roads that are opened through them remain through the whole year deeply covered with mire. The only means known of keeping the forest ways dry, is to give them a width of from 260 to 330 feet; that is to say, to clear the country in their course."

Deficiency of Water Follows Forest Destruction.

A remarkable instance of how running water diminished by mere evaporation, without falling off, even with the increase of the yearly quantity of rain, is related to us by Boussingault. The metalliferous mountain of Marmato is situated in the province of Papayan, in the midst of immense forests. The stream along which the mining works are established is formed by the junction of several small rivulets, taking their rise in the tableland of San Jorge, which overlooks the establishment, and is thickly wooded. When Boussingault visited the place in 1826, he found only a few miserable cabins inhabited by negroes, but on his return in 1830 the country had the most flourishing appearance. It was covered with workshops, had a foundry for gold, machinery for grinding and amalgamating the ores, and a population of nearly 3000 inhabitants. It may be imagined that during these four years an immense quantity of timber had been cut down, not only for the construction of machinery and houses, but as fuel and for manufacturing of charcoal. The felling had princi-



"Of all the destroying influences man brings to bear on nature, cattle is the worst."—Hillebrand, July, 1856. A gulch denuded by cattle, Koolau Mountains, Oahu. Photographed December, 1919.

pally gone on on the tableland of San Jorge. But scarcely had two years elapsed before a notable diminution of the water in the stream was noticed. The volume of the water had been measured by the work done by the machinery, and actual gauging at different times showed the progressive diminution of the water. The question assumed a serious aspect, because at Marmato any diminution in the quantity of water, which is the moving power, would of course be attended with a proportionate diminution in the quantity of gold produced. As soon as the diminution of the stream was ascertained, a rain gauge was set up, and in the course of the second year of observation a larger quantity of rain was gauged than in the first year, although the clearing had gone on, still there was no appreciable increase in the size of the running stream. A very similar observation has been made on the Island of Ascension, where an excellent spring

at the foot of a mountain originally covered with wood, dried up when this was cut down, but reappeared in former abundance when the mountain was planted again. Such remarkable effects, arising from the operation of causes limited to narrow localities, cannot be attributed to a diminution of rain. In the first cited instance there was even in one year an uncommonly large fall of rain—undoubtedly accidental. Undue evaporation only can be assumed as the sufficient cause.

The Theory of Condensation.

Let us now see how forests may affect the absolute quantity of rain, or precipitate of atmospheric moisture. From the surface of the water and the exhalation of plants and animals a constant evaporation of watery vapor is carried on. The vapor, consisting of an aggregation of small vesicles, according to its lesser specific gravity, rises steadily from the lower and warmer to the upper and colder strata of the atmosphere. Every gas, under a given temperature, can only take up a certain maximum of moisture; when it has reached that, we call it saturated. When it is saturated, any addition of vapor will be condensed again to water. The lower strata of the atmosphere, being warmer than the upper ones, take up a larger quantity than the latter; consequently these will be saturated, while the former still retain capacity to take up more. As soon as this point is reached, all surplus in the upper regions will have the effect to coalesce those countless invisible vesicles in a lesser number of larger ones, whereby they become visible to the eye as clouds. The more this condensation proceeds, the heavier the vesicles will become, until their specific gravity exceeds that of the atmospheric air, when they fall down. In their downward course they steadily grow by appropriating to themselves the surplus of the lower strata, which, by their contact, are suddenly cooled down beyond their saturation point, and reach the earth as rain. Not unfrequently it happens—and we in Honolulu may witness the sight almost daily—that when a rain-cloud has to pass, in descending through a drier stratum of atmosphere, whose temperature is considerably higher than its own, it dissolves again by evaporation and disappears. The same effect, of course, is produced by dry and warm winds. But any strong wind may, for a limited locality, become a cause of disturbance, inasmuch as its impetus will overcome the specific gravity of a cloud. From these preliminary considerations it seems to be a lawful deduction, that any causes which increase the moisture of the atmosphere in general, and lessens the temperature and dryness of the lower strata, will augment the fall of rain. Have forests a tendency in either of these ways?

How Forests Increase Rain.

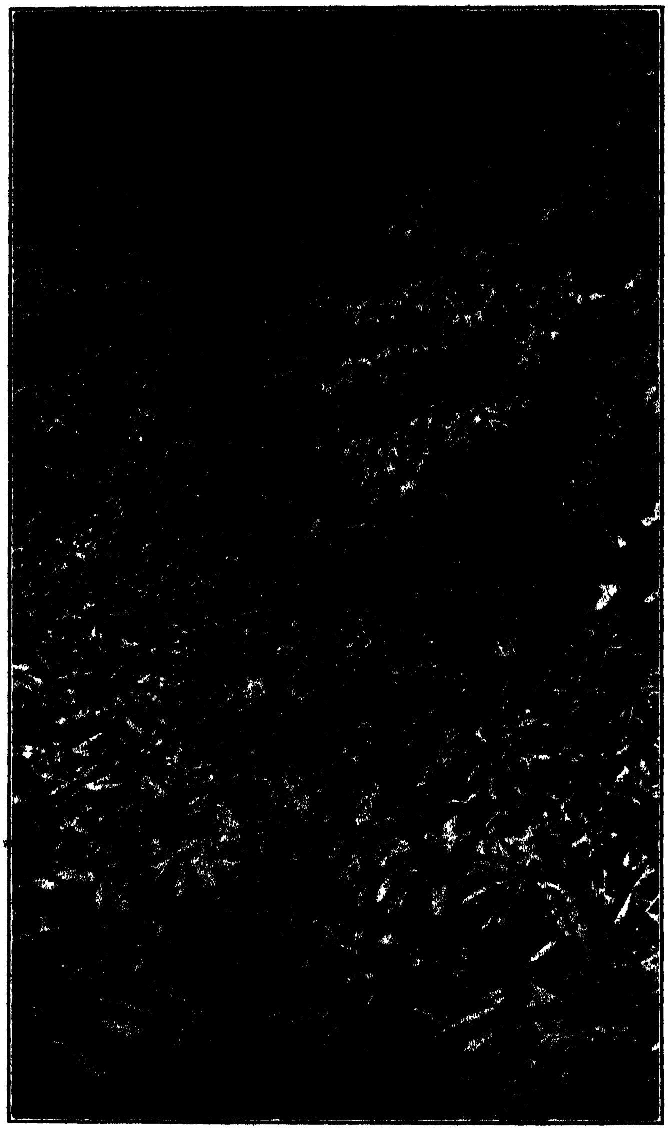
The great source of atmospheric moisture is the vast expanse of flowing and standing water; for an insular climate it is the paramount one, against which all other sources sink into insignificancy. But different is it with vast tracts of wooded land in the interior of a continent, particularly where a high wall of mountains forms a barrier to the sea wind. There the amount of moisture exhaled in the vegetating process will play an important part; and, indeed, Humboldt considers it as the great factor by which forests increase rain.

Far different, however, is it with regard to the second question. Do forests

contribute to cool the lower atmosphere? A child knows that a shade affords coolness by intercepting the rays of the sun, and any one superficially acquainted with the laws of natural philosophy can tell you that a dark-colored surface, as the sapgreen of leaves, imbibes the rays of caloric, while a light one, like sand or limestone, reflects them, and thereby heats the ambient gaseous medium. The imbibed heat again is spent in hastening the evaporation of the water contained in the leaves. But in evaporation of liquid a considerable amount of caloric is bound as latent heat, which is abstracted from the ambient medium. Pour a drop of ether on your hand and you will soon perceive the cooling effect of its transition to gas. Similarly the exhalation of plants. Thus the forests may operate in a variety of ways towards reducing the temperature of the lower strata of atmosphere, and therewith their point of saturation.

Origination of Dew and Its Relation to Vegetation.

But these are not the only, perhaps not even the principal, ways in which forests contribute to fix the atmospheric moisture. Let us consider how dew originates. A general property of all bodies is that of radiation of heat. A body will constantly emit heat to the surrounding mediums, and only keep up a steady temperature, when it receives as much as it gives off. Different bodies possess this quality in a different degree: gases and atmospheric air have least of it, most of all organic substances, particularly such as combine greatest surface with least bulk, as cotton, wool, feathers. During a clear and calm night, when the great generator of caloric, the sun, has sunk below the horizon, and no other source of heat is left but the imperceptible one of the proper heat of the earth, all bodies will steadily lose heat by radiation towards the upper regions of the atmosphere, for these being greatly cooler than the lower ones will abstract heat without rendering an equivalent. Any fast-cooling body will, by lowering the saturation point of the surrounding atmosphere, precipitate the vapory moisture in it; a principle upon whose application Daniel's hygrometer is constructed, and upon which rests the formation of dew. Dew is only observed during calm and serene nights; whatever obstructs the free communication of the lower and upper regions of the atmosphere, as clouds or smoke, prevents the formation of dew, because it lessens the radiation towards the upper atmosphere. A wind likewise will interfere with the formation, as it brings warmer air in contact with the radiating body. You all will be aware that you enjoy the most refreshing sleep during a calm night with an open starlit sky, while the air becomes sultry and oppressive when the heaven is clouded. Grass and leaves being in themselves strong radiators will cool the more rapidly, as they have only a slender communication with the earth, by which the acquired sun heat of the latter might be conveyed to them. Thus a thermometer laid on the bare ground will stand from ten to fifteen degrees higher than one suspended between the grass. For this reason grass and trees are covered with dew, when rock and stone are not, and are dripping when these are moist. In tropical countries this phenomenon must necessarily appear more striking on account of the greater diffusion of watery vapor at elevated temperatures. "In the bivouac on the edge of the forest of Cauca, between the fourth and fifth of July," says Boussingault, "the night was magnificent; nevertheless, in the forest,



Cover of Kukui and ginger, the ginger being an introduced species. Photographed December, 1919.

which began at the distance of a few yards from our encampment, it rained abundantly; by the light of the unclouded moon we could see the water running from the branches." Those of you who frequently have to repair to our mountain woods know that if they go before the sun has moved near its meridian they are likely to have wet feet, even though it had not rained during the night, and the open plains appear dry.

Process of Emanation in a Forest.

What I have said with regard to emanation of heat has only reference to the nightly formation of dew, which, although of less consequence for most countries, plays a most important part in countries where it hardly ever rains, as in the district between Payta and Lima. Let us, however, carry our considera-

tion a little further. If we apply the law of emanation to a large tree, we find that free radiation can only proceed from the crown of the tree. The lower branches cannot radiate towards the sky, as the upper ones act in the manner of a screen; but in the measure, as the leaves of the crown cool off, the next lower ones will emit heat to them, which these will again send off towards the sky. The same process is thus continued progressively from all the upper to the lower branches, and the amount of caloric withdrawn from a given area grows in progression. Of course, the air circulating between the leaves participates in the loss. In this manner Humboldt has calculated that a tree which presents a horizontal section of not more than one hundred and twenty or one hundred and thirty square feet, actually influences the cooling of the atmosphere by an extent of surface several thousand times more extensive than this section. What a condensing power is thus created in a tropical forest! Aside by this *a priori* deduction set the fact, that in wooded tropical regions about seventy per cent of the annual average of rain falls during the night, and you will find the connection between cause and effect immediate. The effect of such an amount of cooling down, it is easily conceived, cannot be limited to the night alone, but must necessarily extend at least over a great part of the day. Thus we may contend with full reason that forests cool down the average temperature of a country, and thereby contribute powerfully to the condensation of atmospheric moisture in the shape of rain or dew.

It was long maintained by many observers that forests could have no influence on increasing the annual quantity of rain, however much they might contribute, by lessening evaporation, to keep up a due amount of running water, or to regulate the fall of rain over the different seasons. The aggregate amount of rain falling on our globe, or even within defined zones, in the course of a year, probably does not vary as long as the sun continues to send us every year the same amount of heat. But certain localities may be enabled to appropriate to themselves an uncommonly large proportion; and perhaps there prevails even in the grand chain of cause and effect in the universe, the law of commerce, that the consumption regulates the production. The quicker the atmosphere is debarrassed of its load, the sooner it will charge again. Be this as it may, experience seems to have decided the fact, that for given localities forests increase the mean annual quantity of rain.

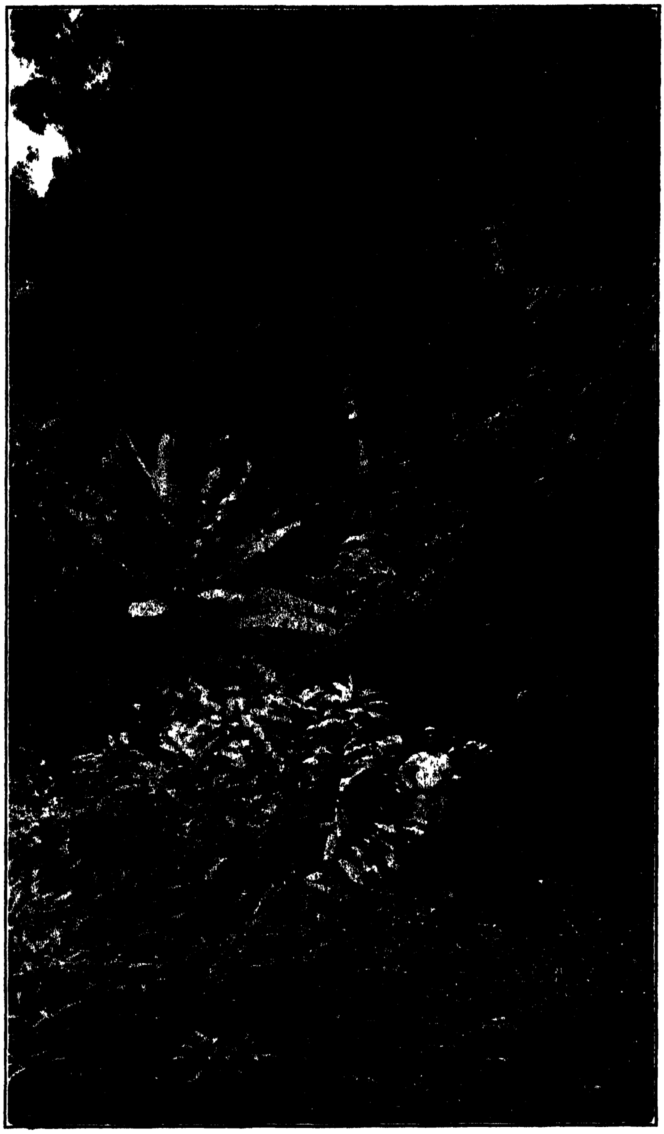
St. Helena, an Example of Increase of Rainfall Due to Forests.

In St. Helena, where extensive plantations have been carried on for a number of years, careful observations show that the yearly average of rain has almost doubled since the time that Napoleon was a prisoner in Longwood, and the torrential floods, formerly so common, have not occurred for the last nine years. The most remarkable instance in point is probably the lake Aragua in Venezuela. This large inland lake, bounded on all sides by high ranges of mountains, which pour in their waters, and at the same time debar its outlet, was seen and accurately described towards the end of the sixteenth century by Oviedo, who says that the town of Valencia was founded 1555, at the distance of half a league, or one and a quarter English miles, from the shore. When Humboldt visited the valley in

1800, he found the town three and a quarter miles removed from its banks. What formerly had been described as isles or shoals, were now main land or peninsula, and new isles had arisen from under the surface of the water. Rich bottom lands had been gained by the retrocession of the water, which were covered with flourishing plantations of cotton, sugar, and cacao. The whole valley bore the loveliest aspect, covered as it was with the work of industry and labor. Even the slopes of the hills had been stripped of their trees and transformed into corn-fields. The retrogression of the lake had been noticed by the inhabitants with astonishment, and was generally ascribed to a subterranean outlet. Humboldt's genius divined the true cause, and from it threw out the warning with which I introduced the present investigation. Some time after his leave the war of liberation broke out, slavery was abolished, hands and capital were drawn off for many years, and the flourishing plantations went to ruin. The maize and corn-fields on the slopes gave way again to brushwood and forest, which sprang up quickly, with that exuberance proper to the rich gem of the tropics. Twenty-five years after Humboldt, Boussingault visited the place, and now found that the water of the lake, instead of continuing to recede, had risen perceptibly, submerging the isles of new formation and swamping the cotton fields on the rich bottom lands.

INSTANCES OF RAINFALL DIMINUTION INDUCED BY FOREST DESTRUCTION.

Lakes without exit which receive the waters of hill-bound basins of considerable extent, are certainly the best test gauges to apply to the present question. Observations in regard to them are manifold in all continents. So Boussingault infers from numerous data, that the two lakes of Ubaté and Zimiyaca in New Grenada, two centuries ago, only formed one sheet of water. The country round them has since been cleared of woods for the supply of fuel for two neighboring salt springs. And as a contrast, he remarks the lake of Quilatoa, not far from the former, which was exactly measured by Condamine in 1738, was found by him in the same limits in 1831. This lake is situated at an elevation of 13,000 feet, uninfluenced by the effects of agriculture and vegetation. Similar are the conclusions Saussere arrived at from a careful study of the lakes of Neufchatel and Brienne, and Morat, and those of Humboldt with regard to those of Southern Siberia. Hindostan also offers some direct instances to the point. On the high tableland of the Dekan the annual rainfall averages from 60 to 200 inches; but in some of its districts, which have been extensively robbed of forests, precise observations show only a fall of 10 to 25 inches. The reckless destruction of the spice trees on some of the Banda Islands, prompted by Dutch avarice, has converted these gems of the sea into as many bare rocks. From the Cape de Verd Islands sounds this moment a cry of distress. The usual drought which since the destruction of the woods befall these now to rock and sand reduced islands (for three successive years they have had no rain) have again produced one of their regular effects. Famine and disease had slaughtered already six thousand of their wretched inhabitants before the beginning of April, and two thousand more, so says the proclamation of the Portuguese governor, would fall by the scourge before the end of summer unless charity from abroad sent relief. I could multiply my illustrations, but shall



Along a ditch trail, Koolau Mountains, Oahu, showing good forest cover. Photographed December, 1919.

conclude with calling attention to the state of climate on the Pacific coast of South America, from the Gulf of Darien down the coast of New Grenada and Ecuador, in contrast to the immediately following coast of Peru. Both are, so far as mean annual temperature, proximity to the sea and high mountains, prevailing winds, etc., are concerned, similarly situated; but the former is densely covered with forests, while the latter is remarkable for its total absence of the same. Now, what is the result? The former is supplied abundantly with rain; in the province of Chocos it rains almost incessantly, while in Payta it has not rained once in seventeen years. One tract of the Peruvian coast, "Sechura," derives its name from this circumstance. It is well known that the inhabitants of Lima consider roofs a superfluous incumbrance to their houses.

I might still enlarge upon the fertilizing agency of forests in fixing the

carbon of the atmosphere, thereby supplying the soil with humus, or the great superiority of rain over running water, inasmuch as the former precipitates, in the shape of carbonate of ammonia, the nitrogen so indispensable to the most nutritious parts of a plant. I could demonstrate to you that the mud which now threatens to fill your harbor, and exposes you to the heavy expense of dredging it, would for the greatest part have been retained on the inclined planes of your valleys, to become as useful as it is now annoying, by the presence of trees, if I did not fear to draw out to undue length my present discourse.

What Is the Golden Middle Road?

Thus the testimony in support of our main question has accumulated so as to raise it beyond all controversy. Extensive forests will render the climate cool and wet, while absence of them imparts to it dryness and warmth. The former engender a multitude of brooks and rivers, swamps and lakes, and envelop the surface in mists and fog; the rains are equally distributed over the seasons; the difference between the mean temperature of summer and winter is small; agriculture will only prosper where the aggregate amount of summer heat is large enough to mature its products—that is, in lower latitudes. The latter condition gives to the country a clear unclouded sky; the difference between summer and winter temperature becomes excessive; the winters are colder, the summers warmer; the rains either disappear or are limited to one short season, in which they fall with extraordinary violence and overflow the generally dry beds of the streams; vegetation is suspended during a greater part of the warm season. Neither of these conditions of climate is particularly favorable to agriculture. Here, as everywhere, the golden middle road is the best. Clear enough ground to allow the sun to exercise an impression sufficient to accumulate during the vegetating season heat enough to mature the seed and fruit, but retain trees in sufficient number to attract and economize the necessary supply of moisture, indispensable to all organic beings. Now it will be clear how in one place agriculture will appear to have changed a wilderness into a lovely garden, swelling with the richest offerings of Nature's choicest gifts; while in another the arid sand of the desert settles down where reckless selfishness of man, in its steady combat with Nature, succeeded in routing the latter. There we see the first stage, here the second of the grand revolution. What a terrible warning! What an amount of wholesome instruction is contained in this reflection!

The Selfishness of Man in the Wanton Destruction of Nature.

No one has more forcibly expressed these sentiments than the venerable veteran amongst the eminent naturalists of our age, Elias Fries, of Lund, in Sweden: "A broad border of devastated land follows progressively the steps of cultivation. With its extension its center and cradle dies, and only in the circumference are found its green branches. But it is not impossible—difficult only for man—to repair the damage he has inflicted without renouncing the blessings of cultivation itself. He is destined to be the Lord of creation. It is true thistles and thorns, ugly and venemous plants, poignantly called dunghill

plants by botanists, trace the path which man has traveled hitherto over the earth. Before him lies primitive nature in her wild but sublime beauty; behind him he leaves the desert, an unseemly, exhausted land. For childish love of destruction, or improvident waste of the vegetable treasures, have annihilated the character of nature, and, frightened, man himself flees from the scene of his misdeeds, leaving to savage tribes or the wild beast the degraded earth, as long as another spot allures him in virgin beauty. Here also, seeking selfishly his own gain, and following aware or unaware the most abominable principle, the most execrable immorality ever enunciated, *'apris moi le deluge,'* he begins anew his work of destruction. Thus the moving cultivation left the East, and earlier perhaps the desert; spoiled of its vestments, thus it abandoned the whilom beautiful Greece to savage hordes. Thus this conquest rolls with stupendous celertiy from east to west, through America; and there now already the planter leaves the exhausted soil of the eastern shores, the climate rendered unproductive by the annihilation of the forests, to imitate in the far west a similar revolution. But we see also that noble men, of truly cultivated minds, commence to raise their warning voice to begin on a small scale the second more laborious task, to restore Nature to her strength and vigor. Truly, this undertaking is at present feeble, and disappears in view of the great object to be attained, but it preserves the faith in the destiny of man and in his power to fulfill it. In future man will and must succeed to free Nature, while controlling, guiding and protecting her, from the tyrannical slavery to which now he debases her, and in which he can only maintain her by a never-ending struggle against the eternally rebellious. In the dim distance of the future we see a reign of peace and beauty on earth and in nature, but before man reaches it he will have to take many lessons from nature, and before all, emancipate himself from the chains of egotism."

Education in Forestation.

Indeed, the attention of scientific men and governments has been seriously aroused to the importance of the subject. More than forty years the maintenance of existing and nursery of new forests has been a prominent care of the German states; not so much at first from a proper understanding of the enunciated principles as from the necessity to keep up a due supply of fuel and timber. At present, however, these principles are fully appreciated, and the extensive plantations on naked hill ranges or unproductive plains give ample evidence of it. A special branch of officers is appointed by governments, municipalities, and large land owners, to watch over the interests of the forest; and special schools, distinct from those for agriculture, are established and liberally endowed for instruction of pupils who devote themselves to this particular study. In Germany the schools of Tharand and Hohenheim, in connection with the name of a Cotta and Hartung, have signalized themselves. At a meeting of the British Association at Ipswich, in 1852, the subject was profoundly discussed and its importance seriously pressed on the attention of the English public. In Hindostan the East India Company has taken vigorous steps to inhibit the destruction carried on formerly, and to fill up by plantations on a large scale the void produced by them.

Application of the Lessons of History to Hawaii.

So far, gentlemen, I have entertained you at great length of time with the disastrous influence of civilization upon climate and nature at large. But where, will you ask, is the application to our young country, where civilization only dates since yesterday; where agriculture is just beginning to impress upon it the stamp of refinement and embellishment, which you before described as its first stage? I will admit for a moment the validity of your objection. In that case my answer is this: if there are no faults and wrong doings of men that need correcting, it is the short-comings of nature which I should wish to see assisted and hurried on. To speak more plainly, the gist of my foregoing remarks is, that a certain amount of perennial, high and dense vegetation is necessary to secure the interests of agriculture on a permanent basis; that in other countries this condition existed but has been destroyed by man, but that our country has not reached a sufficiently advanced age, wherein nature might have accomplished its great end of covering the earth with vitalized beings, which are necessary to complete the great cycle of action and reaction on each other of earth and atmosphere.

It may safely be presumed that when the mighty fiat first sounded over the great expanse of land and water, the ocean quietly rolled its billows over the spot where now our archipelago has risen. When those immense forests of Calamites, Sigillarias and Lepidodendrons accumulated in the bottom lands of receding waters, to be submerged by the flood; which again receding, left their debris covered with a deposit, thus again forming the ground-floor for a new vegetation, only to be buried and to resurge by the same process—that epoch is probably far anterior to the birth of our Islands, which, besides the immediate compounds of Vulcan's subterranean fires, do not present to the geologist but formations of the latest epoch. There are even reasons to suppose that organic life began here a long time after the last configuration of the earth-crust, after it had made considerable advance in other parts of the globe. Yet our Islands have a creation of their own, even peculiarly their own, from which starting nature began in her slow progress to cover every spot, as it became inhabitable for organized beings.

The Migration of Plants to the Islands.

Soon the waves scudded along from distant regions a stray cocoa-nut, a hard-shelled bean or pandanus seed; the winds carried over the almost microscopical spores of cryptogamous plants and seeds endowed with wings or parachutes (although the smaller number of plants with this kind of seed in common with neighboring countries might make us infer, *a priori*, our great remoteness from them), birds dropped a small amylaceous or grass seed, entangled in their feathers elsewhere; and last of all came man, bringing with him the means of his sustenance—probably the banana and bread-fruit. But man, after having been deposited here, was cut off from his anterior home, and therefore with, or soon after, his arrival, his agency ceased. Only with the appearance of the white man another era dawned; he at once bound this isolated group to the five continents, and established a highway on which what

lived or breathed in distant regions might wend its way hither. What to accomplish, nature alone in her slow but steady way would have required hundreds of years, the intellectual, analyzing, and combining power of man, penetrating and imitating her own laws, may do in as many decenniums, not indeed on such a gigantic scale as nature is wont to do it, for with all his application and energy his works will ever remain dwarfish when compared with her immense powers; but on a small scene of action, when his works are favored by the forces of nature, he can make a great impression on the physiognomy of a country.

Wherever the white man goes he carries with him his accustomed means of sustenance; the cereals follow him like his shadow. With the cereals he spreads involuntarily the seeds of weeds whose favored habitat is with them. Culinary vegetables, fruit trees, ornamental plants follow next, a great many of which soon acclimate and become naturalized. Many wild plants stick to his steps, as it were, as an indispensable accessory, although neither utilitarian reasons, nor particular aptitude for transmissibility in the seed, account for it. Thus the plantain, *plantago major,* invariably sprung up where the settler in North America raised his cottage. The Indians still call it the white man's footstep. It has followed him here. Another plant growing around you, the thorn apple, St. James' weed, *Datura Stramon,* originally an East Indian plant, spread from there with the migration of the Gypsies over Asia and Europe; from Europe the white man carried it to America, Africa, and Australia. During the great war movements of 1814 and 1815 it was observed that a *Siberian Corispermum* sprung up wherever the Cossacks had pitched their tents in Germany. From America the *Erigeron canadens* spread over Europe; from there it went with the colonist to other continents. The vegetable migrations following, as it were, spontaneously in the wake of man, are as many agencies in increasing the vegetable stock of a new country; but they will fall short of the vast auxiliary which can be offered to youthful nature by the thinking mind of man, when he takes the light of science as a guide to investigate the true wants of the country, and directs her energy in conformity with the organic laws of nature.

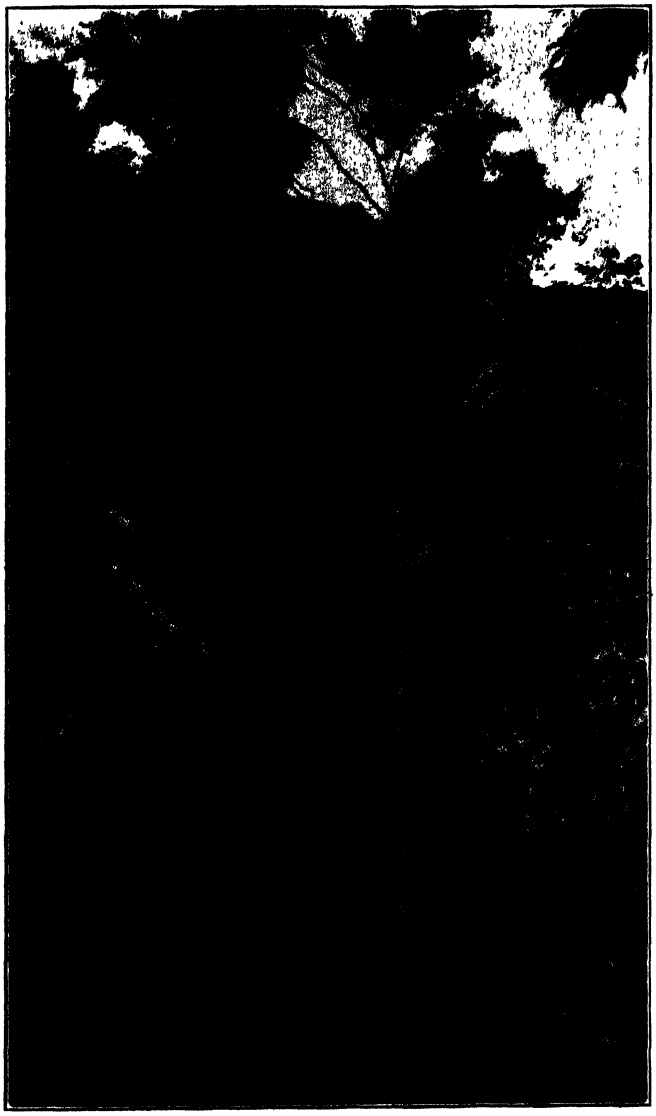
Opportunity for the Introduction of New Plant Life.

This, my friends, let us endeavor to make our great aim on these virgin islands, where we have met together from so many parts of the world to be formed into a homogeneous community. Rare advantages accrue to us from the various combinations of elements of which our rising state recruits itself. The matured experience and knowledge of many nations is centered in your society. You are situated on the central station of important commercial lines and have direct communication with four continents and many island groups. The great variety of your climate permits you to appropriate to yourselves most productions of warm and temperate zones. Insufficiency of perennial vegetation is the only true cause which renders our Islands so far inferior in their resources to the islands of the East and West Indies. Take a survey of the different districts of our group. Those you will find the most productive which are in the neighborhood of, or surrounded by wooded mountains, as Hilo and Kona in Hawaii, and Hanalei in Kauai. Go to work then to fill up the lacunas left yet by nature. Cover the dreary dark of our naked hills with the fresh verdure of shrub and

tree. Intermingle the lofty pine and cedar with the graceful acacia, the stately eucalyptus, the broad shaded tamarind and ceiba! Between them rear the towering teak tree of India, and the gigantic sequoia of California, to yield in times to come the solid timber for your nascent shipping. The dark foliage of the orange and citron, serving as foil to their golden fruit, must cluster round the cool moss-inlaid springs, which will soon bubble forth as if struck by Moses' rod, from every nook and corner between rocks, and under the fern tree, to unite in rivulets and streams which, encased in a framework of bamboo cane and lianes, will pour out of every valley, and cover with fertility the now arid and sterile plains. Then these will swell, as if Pandora's horn were emptied over them, with the turgid cane, the fragrant coffee, the speckled cotton and broad-leaved cacao, while here and there a copse of wood and shrubbery will offer shelter and food to those lovely songsters whom you are so anxious to admit into your society, but who certainly will shun it unless you build them convenient houses, and plant them food of their liking. Thus your Islands, looming over the distant horizon, encircled with a columnar row of massive cocoas, graceful arecas and stately coryphaenas, will indeed appear to the approaching stranger like a cluster of gems in the wide ocean, bidding fair to realize the fanciful dreams of his youth.

Lack of Conservation of Trees Already in Hawaii.

But before all, let us not neglect the vegetable treasures already accumulated by Nature's own unaided efforts. But here we are suddenly arrested in our fanciful excursion by a sad reflection. Have we really only the grateful task to assist nature, to rear into vigorous manhood the tender child intrusted to our care? Alas! our civilization only dates of yesterday, and already nature bleeds from many wounds inflicted by the cupidity and reckless selfishness of man. Where are the forests of sandal trees, which used to shed a halo of fragrance around the mere name of the Hawaiian Islands? A vast source of wealth has been dried up, a rich mine of gold—whose yield ought to have increased from year to year—has been squandered away, perhaps never to be worked again; for what little there is left of it, mostly crippled shoots of old trunks, bids fair with its slow growth to be stifled and crowded out by meaner, more precocious neighbors. Another source of wealth, whose importance will only be appreciated when our neighbors of California and Oregon have made sufficient progress in industry to be able to dispense with imported furniture, exists in the koa tree, *Acac. heterophylla.* Its many fine qualities for cabinet work make it equal to mahogany; in durability of color it excels the same. If we go on to fell these trees without proportioning the increase to the consumption, this source of wealth is likewise doomed to extinction—a fate which has already befallen the splendid tamani, *Calophyllum inophyllum,* of which only a few relics exist on Molokai. Has any one of you met with a fresh plantation of cocoa palms? How is it that, for instance, here on Oahu the magnificent and productive bread-fruit tree is so little cultivated? Is there a tree more picturesque to the eye, offering at the same time a liberal shade and a most nutritious, pleasant fruit? In the valley of Hanalei grows a tree (of the genus *Xanthoxylum*) called by the natives mokihana, whose seeds, seed-capsules, and leaves are impregnated with a spicy aroma similar to cardamon, but sharper to the taste. It is, to my knowledge, not found in any



This tree is a remnant of the sandalwood forests to which Dr. Hillebrand makes reference. Photographed on an Oahu ranch, December, 1919.

other locality, and to all appearance is indigenous. Unless taken care of, it may be lost, sooner or later, whereas, if propagated and protected, it is likely to become an important addition to the number of known spices, and a valuable article of export.

Encroachment on the Original Forest of Waimea Plains.

It cannot be denied, that in many places the domain of forest has been seriously encroached upon by man, and more by cattle. In the February number of the Sandwich Islands Magazine, an intelligent observer calls our attention to the startling fact that the whole plateau of Waimea, in Hawaii, over twenty miles in length and five in breadth, has been spoliated entirely of its original forest, which only twenty-five years ago formed an impenetrable thicket, by the agency of wild cattle; not a tree or shrub is to be seen now from Kawaihae to

the opposite sea-shore. Mark the effect: for the last nine months, as I am informed, they have not had a rain shower. The extended plain, which, after having been divested of its trees, probably was supposed to yield abundance of pasture to flocks and herds, is parched and cracked; not a blade of fresh grass is to be seen; clouds of dust have taken the place of rain-clouds, and the cattle, to escape starving, have to repair to the side valleys of the Kohala range and Mauna Kea. Do not object to me, that we have had an unusually dry year over the whole group, for I have yet to learn that any other region as elevated as Waimea, 4000 feet above the level of the sea, which has retained its native foliage, has been visited by a similar drought. It is alleged that the climate has improved since this process of destruction was carried on. It is true, raw mists and chilly winds are not so frequent there now, and the squally mumuku has ceased to blow, but perhaps the latter might have been averted, not by killing the vegetation on the high plains of Waimea, but by starting a new one on the slope of Kawaihae, which would have reduced the excess of heat peculiar to that desolate lava region. Besides, it may be necessary to remark here, that salubriousness and productiveness of a country do seldom go hand in hand. For, taking as a measure for general salubrity, the average percentage of deaths by consumption, we find that the healthiest spots until now ascertained are neither Rome, nor Madeira, nor the Provence, but the rainless coast of Malaga in Spain, those parts of Egypt above the Delta, nearest the desert, and, before all, Algiers, where, according to Drs. Haspel and Jourdain, only one death in seventy-five is due to consumption, while in Paris and London the proportion stands one to five.

Disastrous Effects of Cattle and Sheep on Vegetation.

During my short stay in Australia I had ample opportunity to notice the disastrous effects of cattle and sheep on vegetation. In South Australia, for instance, the original flora has almost disappeared on the rich plain between the sea and coast range. Even the formerly impenetrable thicket of the scrub along the river Murray, begins to feel its effect. Perhaps that country, which, almost shadeless on account of the perpendicular inclination of the plane of its foliage, whose tough, leathery qualities almost unfit it for a copious perspiration, lacks of rain for eight months in succession, will in distant future have to regret that its early colonists began their work of civilization with flocks and herds. Of all the destoying influences man brings to bear on nature, cattle is the worst. In what are now the Kirgisian steppes, between the Altai and Ural mountains, Humboldt found a remarkable succession of lakes, from whose relative positions to each other, in combination with the geographical formation of the country, he concluded that they formerly had been united in one sheet of water, which covered the vast plain. The great traveler does not refer to great phyiical revolutions which might have opened an outlet to these accumulated waters, but from more direct observation made in the neighboring steppe of Bareaba, he is led to believe that the presence of man has to account for it. A retrospect in history, however, shows us that this is part of the very country where lived the Scythians, from where issued the Huns, Mongols and Turks, all nomadizing tribes, which to our knowledge had only a faint acquaintance with agri-

culture. Herds of cattle and horses were their sustenance, formed their wealth. Is it not legitimate, therefore, to ascribe to them this great change in the physical physiognomy of this country?

Let us take a warning from such ominous examples. The small area of our Islands is too valuable to be devoted to cattle rearing. Allow them to multiply for all the legitimate purposes of the dairy, home consumption and supply to the shipping. But what goes beyond is of evil. If we rear them for the sake of their hides and tallow, I imagine the expense of producing these is too great. We forfeit by it the vital sources of our soil. It is even questionable if by fostering an export of cured or dried meat we promote our true interests. The multiplication not only, but the existence of wild cattle and goats ought to be set a stop to. Where the interests of agriculture and cattle-rearing conflict, the former should be protected in preference.

Demand for Fuel from Our Forests.

I have not touched yet upon the other evil, arising from the destruction of forests—scarcity of fuel. A few remarks will suffice. In our community this evil is already felt severely at the present time; the high price of fuel attests it. What we consume in Honolulu has for the greatest part to be brought from other islands. And yet we can never flatter ourselves with the hope to find relief in that great resource which unexpectedly came to help other countries over their impending difficulty—fossil coal. For, adopt either of the two propounded theories about the geological history of our Islands, you will arrive at the same result. If you adhere to the hypothesis of a late rising above the surface of the sea, this must have taken place in the latest epoch of the consolidation of our earth's crust; for only coral limestone, with detritus and conglomerations of the basaltic rock, cover the lower surface of our basaltic hills; no rocks of the transition or secondary groups which furnish the beds for fossil coal are seen anywhere. Do you attribute an older age to an Hawaiian, or if you will stretch your imagination a little farther, a Pacific continent, which by gradual subsidence has left the peaks of its highest ranges as our present archipelago, then those plains and estuaries, where ancient vegetation either grew or became accumulated by the rush of waters, must lie now submerged deep beneath the rolling swell of the ocean. Thus our only resource will have to be found in our forests. A little further reflection on our part must still more forcibly impress us with the importance of the subject. The number of species of trees as are well adapted to produce heat for economical purposes, is very limited. The prevailing character of our forests is that of bush and shrub; most of the taller trees are of so light a texture as to be unfit for heating. How does it stand with the fuel trees mostly in use? The ohia lehua (*Metrosideros polymorpha*) has probably in former times been the most prevailing tree over the group. It is not now. I have seen only few scattering rudiments of it, where there are unmistakable indications that formerly it covered extensive dimensions of ground. But the demand for fuel must necessarily grow in proportion to the increase of population and the concomitant necessary establishment of workshops and factories. I do not wish to be understood as favoring the introduction of manufactures at large in our fair Islands; on the contrary,

I most heartily deprecate such an idea; besides, I consider its realization impossible. But there are certain branches of industry a well-organized community cannot dispense with. These are either such as enter into the primary necessities of daily life, but cannot on account of undue bulk be shipped without raising the price quite beyond proportion, or such as can be produced with small labor on the spot where the raw material is raised. To confine myself only to one example. We build our houses of the very material least suited to a warm climate, of wood. Not only does it oblige us to live, or rather to swelter, in an atmosphere often heated almost to the temperature of blood, but it exposes our fast filling villages before long to a great and inevitable calamity. Coral rock, the only other material on hand, commands, on account of the great labor its cutting requires, such a price as to be only within the reach of very few. Besides, it could only be used to advantage for larger buildings. The only good building material which ought to be general amongst us, and at the reach of every one, is bricks. Transport from the United States raises their price to six or eight times their original value. Good raw material is in abundance amongst us; the alluvium on the banks of the river and the deposit in old taro patches chiefly consists of a very stiff clay, the common product of disintegration of basaltic rocks. On the banks of rivers it may be obtained, almost pure, unmixed. On inquiry why no bricks were made here, I have been told that attempts had been made, but the high price of fuel obliged the undertaker to abandon the enterprise as unprofitable. Part of the preceding remarks will also refer to pottery. With regard to this branch of industry it may be of use to record that in Teneriffe, in order to obtain the clay of which those valuable porous water jars, *gargolettas,* are made, the natives build retaining walls at the foot of the mountains, to collect the water which deposits this precious detritus of their trachytic rocks.

THE PROTECTION OF FORESTS AGAINST WIND.

Before I conclude, I cannot but refer briefly to the shelter well-established forests will afford against high wind, by common consent one of the greatest impediments to the successful pursuit of agriculture and horticulture with us. Forests, located with a special regard to the prevailing wind, would be highly beneficial to circumscribed localities. But allow me in this place to advance a hypothesis, according to which, if it should prove correct, the influence of forests in modifying the strength and current of winds, would be of more general application. Honolulu with its environs offers a good example for illustration. The ordinary trades that strike over the plain of Koolaupoko, on the windward side, are broken by the abrupt circular range of mountains which include it like an amphitheatre. Their only outlet of this great *cul de sac,* is the deep notch over the Pali of Nuuanu, elevated eight hundred feet above the sea, into which they crowd with concentrated strength. One should suppose that the lower currents, which swept over the plains of Koolau at a less elevation than eight hundred feet, would, in passing the Pali, assume an upward direction, while the upper ones would continue a horizontal course. Such being the case, they ought to pass at least eight hundred feet over our heads, while in reality, as soon as they have traversed the Pali, they take a downward course

and sweep over the surface of Nuuanu Valley down on Honolulu. As a general rule our nights and mornings are calm; the trades appear in Honolulu about ten o'clock in the morning, and last to five or six o'clock in the afternoon; that is, just as long as the sun's heat rarefies the atmosphere over the lower part of Nuuanu and the plain. If my recollection serves me right, the wooded part of the valley nearest the Pali is generally calmer than any other part of it; the traveler in approaching the Pali, receives the violent gust of wind quite suddenly when immediately near it. May it not reasonably be supposed, that if we lessen the rarefication of the atmosphere in the lower valley and on the plain, by cooling it down through the presence of trees, we can succeed in giving to the ordinary trades a less downward inclination, to raise it, if not eight hundred feet, at least some fifty or sixty feet over our heads? We should still have breeze enough to make us feel comfortable, but our trees would not shed their fruit, and there would be a great deal less of rheumatism in our village. Many other parts of the leeward side of our Islands are similarly situated to Honolulu.

Necessity for Action in the Planting and Importation of Seeds.

It remains for me only to make a few remarks on the practicability of a plan of such extent, as the one propounded undoubtedly is. Of course it cannot be accomplished in one year, or a couple of years. In northern latitudes the raising of a new forest, even of fast-growing trees, will take from fifteen to thirty years. Here our patience will not have to be put to such a stretch. Where, as I had occasion to observe in my garden, some species of Acacia will grow in little more than one year to the height of twenty-four feet, from the seed, Melias sixteen feet, and Casuarinas ten feet, there it may be admissible to feel somewhat sanguine on the subject. It is my opinion that on the banks of rivers and in low wet places our end may be attained in less than four years. In dry, unsheltered plains, bare hills or elevated districts, it may take longer time. Nowhere, I imagine, we shall have to wait more than six or eight years before some results are obtained. The work cannot be done by a few individuals; the whole nation must lay hand on this great national work. And if it were for no other reason than this, I hail with joy this festival occasion which for the first time has assembled our native friends of the National Hawaiian Agricultural Society with us. The same idea has called their society into life, as ours; the same zeal animates them to realize it, to embellish and enrich the fair land of their inheritance. Let every member of our societies enter an engagement to plant yearly a certain number of trees; let our society import seeds from abroad in quantities for distribution, particularly of such trees as are of some economical use; but let us make an immediate beginning with the vegetable treasures, native or domiciliated on our soil. To prevent failures from error in judgment, Government may designate competent persons whose duty it shall be to select and assign places where a beginning may be made with the best advantage, and appoint wardens for the protection of the young plantations. Indeed, amongst all the monuments a wise and great ruler may erect himself for posterity, which are more beautiful and durable than those that will shed blessing and happiness on his nation's children and grandchildren? Which are greater than those which comprise at once every one of his subjects and every

square foot of his kingdom? Which more admirable than such as founded by an enlightened sagacity, penetrating the hidden future, tend at once to avert unseen calamities and secure unhoped for happiness? Works of this character, not their wars, secure to the name of Henry IV, Peter and Frederick the Great, a grateful abode on the lips of the humblest peasant of their nations. Thus amongst the claims on posterity's gratitude, the great Akbar founded himself in India; one, not the smallest, consists in his directing "to plant trees of every description on both sides of the canal down to Hissar, both for shade and blossom, so as to make it like the canal under the trees in Paradise, and that the sweet flavor of the rare fruits may reach the mouth of every one, and that from those luxuries a voice might go forth to travelers, calling them to rest in the cities, where their every want will be supplied."

THE HAWAIIAN PLANTERS' RECORD

Volume XXII. APRIL, 1920 Number 4

A monthly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

Twenty-five Years of Experiment Station Work

Dr. Walter Maxwell arrived in Honolulu on April 2, 1895, on the S. S. China to begin scientific studies of the problems of sugar production in Hawaii. As the first director of the Experiment Station he conducted investigations of such fundamental importance that his work has been constantly consulted by those who have followed him throughout the quarter century of Experiment Station activity in the application of science to sugar production.

In 1894 Hawaii produced 153,092 tons of sugar. So great a part has been played by hydraulic engineering, and mechanical engineering by the individual plantations, their managers and operators, that it is difficult to estimate even in a rough way the extent to which the Experiment Station work has contributed in quadrupling Hawaii's sugar output of twenty-five years ago. Nor is it necessary or desirable to make such an estimate. It is enough to know that Experiment Station work has established itself as an important auxiliary to the plantations and that it is unusually recognized as such.

The Industrial Service Bureau

Through the cooperation of Mr. Donald S. Bowman, Director of the Industrial Service Bureau of the Hawaiian Sugar Planters' Association, the *Record* will in the future carry articles and illustrations pertaining to the work of this newly-organized bureau. The housing of the plantation laborer, his health and general welfare, together with the sanitary engineering problems pertaining to this subject, will receive their due share of attention.

In this issue Mr. Bowman has contributed articles dealing with the housing question, the milk supply of the plantations, and the fly, that menace to the health of man. Next month an article will appear on rat control.

Housing the Plantation Worker.

By DONALD S. BOWMAN, *Industrial Service Bureau, H. S. P. A.*

The one-family house with fenced-in yard, sufficiently large for flower and vegetable gardens, has become the plantation standard. The newer type of dwelling with the bungalow or hip roof is finding much favor. This type of construction has much to recommend it, one of its advantages being better ventilation, as the overhanging roof protects the side walls, permitting the opening of the windows in all kinds of weather.

We show an attractive, convenient bungalow in vogue on Kauai which has much to recommend it. The interior finish is surfaced, the rooms are ceiled, cold water paint and stain are used for decorating, and the attached kitchen has a cement floor, built-in concrete stove with cast-iron top, and a sink of concrete. As will be seen, in the rear of the kitchen is a concrete wash floor surrounded by a concrete wall, the waste water being carried directly into an open concrete drain. This type of individual wash floor is much appreciated by the woman with small children, as she does not have to leave the little ones.

Groups of these bungalows fronting on streets, with yards large enough for a lawn and garden, go to make up the ideal plantation village and are a great contrast to the white-washed barracks of the old plantation camps. On all estates where the bungalows have been erected, great satisfaction is expressed by both the managers and occupants.

In considering housing, many details must be taken into account, such as materials, plans, location, water supply, sewage and waste water disposal, the building

Kauai Bungalow. Note overhanging roof, protecting the sides; concrete floor; kitchen with concrete stove pipe in rear; concrete wash house attached; kitchen roof could be carried over for protection from sun and rain.

Bungalows, showing old and new types of roof construction. These buildings are stained, are attractive, and are situated with good distance between buildings. Ample garden space is provided in rear.

and sanitary laws, etc.; and the buildings should be so constructed as to make the handling of an epidemic of contagious or infectious disease easy. As an example, no double walls or other rat harbors should be permitted, thereby preventing to a large extent plague infection.

In years gone by very little attention was paid to location, the chief consideration being that no cane lands be used. Now, thanks to the home-building idea as expressed in new construction, we have model villages in place of camps.

Pleasant surroundings, with some of the modern comforts and conveniences go a long way to make the worker healthier and more efficient in his work.

Milk as a Food.

By DONALD S. BOWMAN, *Industrial Service Bureau, H. S. P. A.*

Many of our plantations maintain dairy herds for the benefit of their employees, supplying milk at the cost of production. This good work should receive every encouragement, and those plantations which have no dairy herds would do well to consider milk in the light of a most necessary food.

Milk is as near a perfect food as it is possible to obtain, as it contains all the essential elements for normal growth and development. We find it contains the materials necessary to maintain the living tissues of the body, i. e., proteins, and enough of the fats, starches, sugars and mineral substance to furnish energy and growth. Milk contains also a substance whose nature is not yet fully under-

stood, but whose presence in the diet has been demonstrated to affect body growth in animals or man. These substances are known as vitamines, growth determinants, or the unknown dietary factors.

Clean milk fulfills all of the requirements for an adequate food better than any other single foodstuff, and it is the food most needed on the plantation and in a great many instances the hardest to obtain. Infant mortality would be decreased and a healthier lot of youth would result were more pure fresh milk used as food, and not considered in the light of a beverage for the older children. Milk as a source of energy, or as fuel for the body, compares most favorably with other foods.

The energy value of a quart of milk is about equivalent to that of a pound of lean meat or of eight eggs. As a source of energy, cereals are, however, cheaper generally than either milk, meat or eggs, and therefore cereal and milk is the ideal combination of foods to furnish energy in childhood.

Of all foodstuffs, milk is the cheapest and most abundant source of obtaining the essentials for bone formation and growth. Therefore milk should form a large part of every child's diet. How often have we seen ignorant mothers bringing up infants on a diet of coffee or tea to which was added a small amount of canned milk!

A well-regulated sanitary dairy would be a great asset to every sugar estate, and if we are to look to the future health and well-being of the employees, this subject should receive early and careful consideration. Attention is invited to Ralph Borden's excellent article on "Dairying in Hawaii" as a source of information, which will be found in the Industrial Service Bureau file.

The Ayrshire Cow.

The Secretary of the Ayrshire Breeders' Association has recently supplied us with a photograph of an Ayrshire cow, which holds an exceptional record as a milk producer. The following information, accompanying this photograph, is published for such interest as it may possess in connection with the plantation dairy:

"'She's a grand wee Coo,' and all dairymen irrespective of breed will pay their homage to Lenetta, the twenty-one-year old Ayrshire who has just completed an Advanced Registry record amounting to 11,138 lbs. milk, 374.73 lbs. fat. In the face of present-day world records, 11,138 lbs. milk, 374.73 lbs. fat, would be considered just an ordinary production, but, nevertheless, it is a world record over all breeds, for no cow of any breed has ever equalled that record officially at the age of twenty-one years.

"Lenetta illustrates Ayrshire persistency and the breed's ability to produce and reproduce. She was born August 16, 1898, and was bred by A. A. Hunnewell of New Gloucester, Me., and is owned and was tested by Dr. John A. Ness of

Lenetta, the 21-year-old Ayrshire cow.

Auburn, Me. As a fourteen-year-old she officially tested 13,248 lbs. milk, 465.74 lbs. fat. She now has five A. R. records to her credit, averaging 11,472 lbs. milk, 397.36 lbs. fat, all of the five records being made after fourteen years of age. She has been a uniform producer, her average of 11,472 lbs. milk comparing well with last year's record of 11,450 lbs. milk and this year's record of 11,138 lbs. Lenetta is a strong, vigorous cow in spite of her years, and looks capable of continuing the good work for quite a few years yet. She has been a regular breeder.

"Cows of this type are the backbone of the dairy industry."

[H. P. A.]

New Intermediate Conveyor.

An idea, which has been in the mind of Chief Engineer Joseph Meinecke, of the Maui Agricultural Company, for several years, has taken concrete form this season as the *Meinecke Intermediate Chute Conveyor,* patented, illustrations of which are shown in Figs. 1 to 4. The photographs show two of the conveyors installed in the Maui Agricultural Company's mill, and the parts of one of the old slat conveyors which was discarded.

One of the greatest sources of annoyance to mill engineers, and of time lost in grinding, is the intermediate conveyors. As soon as the chains begin to wear, their breakage causes frequent shutdowns on the mills, with consequent increase in cost of manufacture. On some mills 75% of the shutdowns are due to the intermediate carriers.

The new conveyor has no moving parts, but is simply a chute built on

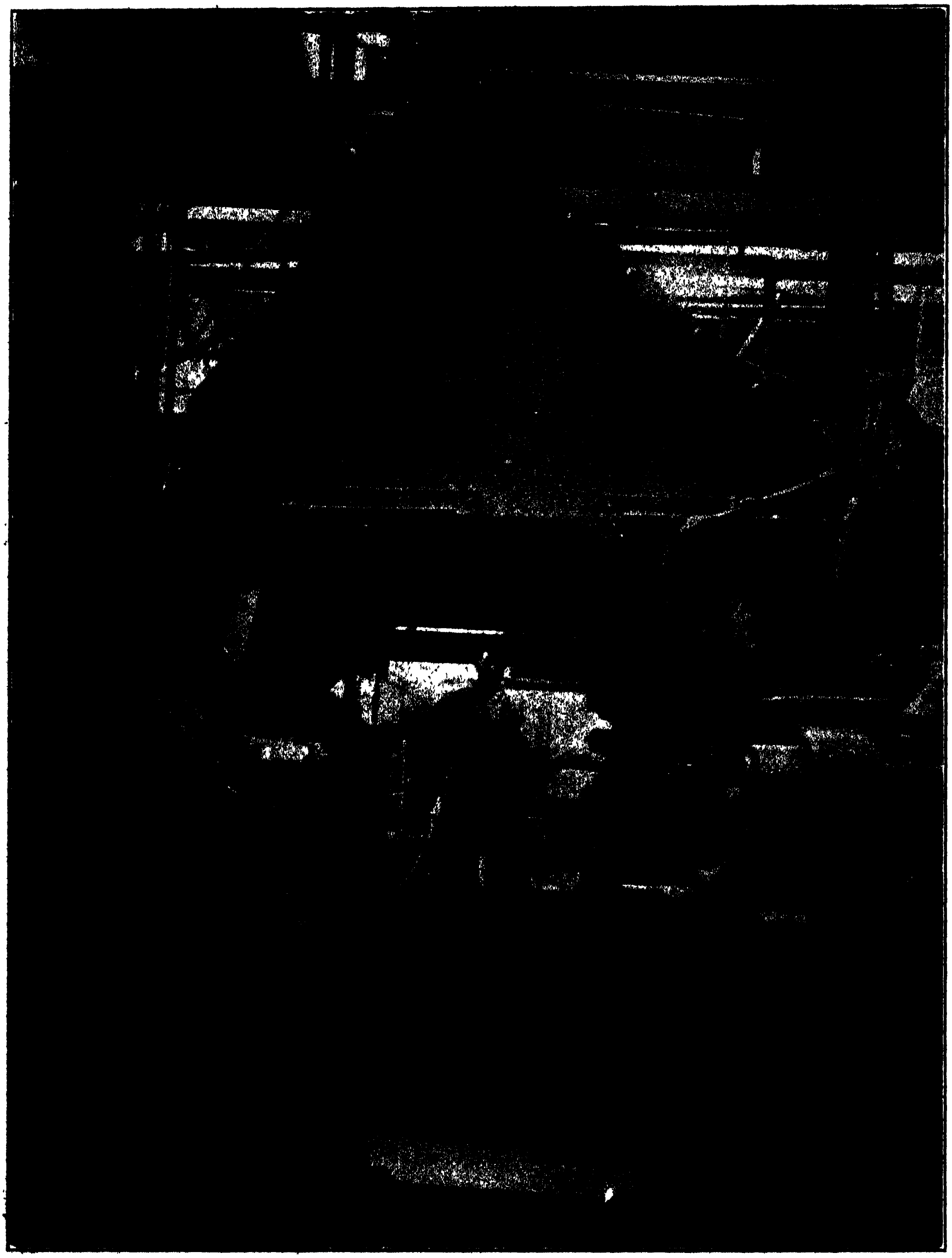


Fig. 1. Meinecke Intermediate Chute Conveyor for Cane Mills. Side view.

Fig. 2. Meinecke Intermediate Chute Conveyor. Back view.

Fig. 3. Meinecke Intermediate Chute Conveyor. Front view.

Fig. 4. Machinery replaced by one Meinecke Intermediate Chute Conveyor.

proper lines. The mill itself forces the bagasse up in the conveyor to a certain height, from which it falls into the next mill. As there is nothing about the conveyors to get out of order, and they work automatically, they require no attention.

R. S. N.

Note on Pineapple Wilt Disease at Kuoolono Park, Kauai.

By C. W. Carpenter.

A recent observation by Mr. W. D. McBryde of Kauai is of interest in relation to a possible means of control of the pineapple "wilt" disease. A section of young pineapple plants sprayed with Bordeaux mixture several times for the control of "heart-rot" early in 1918, at the writer's suggestion, is now found to be not only free from "heart-rot," but also comparatively free from "wilt." The surrounding areas of plants, which so far as can be determined have the same history except that no Bordeaux was applied, are suffering badly from the "wilt."

It seems incredible that the present difference in the appearance of the respective plots of ratoons could be the result of a few sprayings with Bordeaux applied to the plant crop nearly two years ago, when the plants were some nine months old, but since the application of the Bordeaux appears to be the only factor which can be held responsible, the history of the case is briefly recorded for what it may be worth. It should be pointed out, however, that the data are indeed meager, and inferences and conclusions as to the value of this treatment should be held in abeyance until such time as more exact experiments shall furnish a more substantial basis.

In November, 1917, several pineapple plants affected with "heart-rot" were submitted to the writer by Mr. McBryde with a request that the matter be investigated. This trouble was diagnosed as due to bacteria working in the tender tissues at the base of the young central leaves. The field was visited, and since a relatively small number of plants were as yet affected, scattered here and there over a restricted area of several hundred square feet, it was recommended that Bordeaux mixture be sprayed on the affected rows, together with the adjacent sound rows of plants at each side. The plants were some nine months old with open crowns, and it was thought that small accumulations of Bordeaux in the central leaf bases would prevent any further spread of the "heart-rot" disease.

The pineapple field under discussion occupies the gentle slope of virgin grass land makai of Kuoolono Park. Some forty rows running across the face of the slope were sprayed, leaving large areas of untreated healthy plants both above and below. It was advised that the spraying be begun with a weak Bordeaux, gradually increasing the strength when it was found the plants would stand it. Accordingly, Bordeaux spray was applied as follows at intervals of about ten days: copper sulphate, 2 pounds; quicklime, 2 pounds; water, 50 gallons, applied twice. The 3-3-50 formula was applied three times, and the 3½-3½-50 formula twice.

Upon inquiry May 24, 1918, as to results, Mr. McBryde wrote me as follows regarding the "heart-rot" disease, no mention being made of "wilt" disease: "My man in charge sprayed the plants with the Bordeaux mixture and increased the strength from time to time when he found the plants could stand the stronger spray. The disease (heart-rot) finally disappeared, whether due to the spray or climatic conditions I am unable to say; at any rate, we are not troubled with the disease at this writing."

It has been noticed for some time now that in the section where the spray was applied, the plants were larger and more vigorous, and the plant crop of fruit was more uniform. The color of the plants is much better and contrasts markedly with the rest of the field above and below, which is suffering from a bad attack of "wilt" disease. Since the spraying early in 1918 is the only factor in Mr. McBryde's judgment wherein this good section differs in culture from the rest of the field, he is convinced that the spray has in some way been instrumental in maintaining the health or enhancing the vigor of these plants. It is understood that on the strength of his findings large areas will soon be sprayed experimentally by him and by others to determine if Bordeaux mixture is indeed of any value in preventing "wilt."

When it is recalled that in our present judgment "wilt" is caused by a parasitic root fungus (allied to *Pythium*) active under as yet unappreciated soil conditions, it appears probable that if Bordeaux is of value it will be chiefly so as a preventive through increasing or maintaining the vigor of the plants in new plantings and unaffected or but slightly affected "wilt" fields, and cannot be expected to rescue plants in the final stages of "wilt."

Whatever benefit may have resulted in this case from applications of Bordeaux mixture seemingly is a result of the stimulating action of the copper upon the chlorophyll, etc., of the leaves. There is considerable foundation in the literature for the belief that entirely outside of the realm of plant diseases, etc.,

copper sprays exert a beneficial action upon the starch-manufacturing apparatus of the leaves. To quote from Strassburger's "Text-Book of Botany": "It has been discovered that by the presence of certain substances in themselves of no nutritive value, the absorption of actual nutritive matter is increased. In the case of the very poisonous copper salts, experience has taught that when they are brought into contact with the leaves * * * they exercise a beneficial influence on the formation of chlorophyll and increase assimilation, transpiration, and the length of life."

It is not considered that sufficient evidence has been brought forward in the literature to show that Bordeaux mixture acts as a chemical stimulus, and whatever benefit may result from the application of this spray to the leaves of plants, beyond its fungicidal and insect-repelling qualities, may possibly be attributed to some other factor than the stimulating action of the copper constituents. The well-known neutralizing power of soils toward metallic salts renders it extremely improbable that sufficient toxic material reached the soil in the brief sprayings mentioned to be active as a fungicide therein.

H 400 Varieties at Waipio.

We have recently harvested at Waipio a series of the so-called H 400 varieties. In the same lot was also included a few plots of Badila. The cane was first and second ratoons, 18 months old when cut. The yields were as follows:

Variety	Yield per Acre		
	Cane	Q. R.	Sugar
H 460	87.4	8.99	9.72
H 431	75.5	7.93	9.52
H 425	86.2	9.13	9.42
H 466	89.7	9.54	9.40
H 427	73.4	7.99	9.18
Badila	78.7	8.57	9.18
H 416	76.8	8.38	9.15
H 465	70.2	7.80	8.99
H 409	72.4	8.62	8.40
H 441	64.2	9.57	6.71
H 463	63.2	10.09	6.26
H 464	57.8	10.28	5.62

H 411 and H 409 are not of much promise for Waipio conditions. H 464 at first gave indications of being a fair cane, but it has now gone back, suffering from what appears to be Lahaina disease.

In the following table is given a summary of the yields of these varieties for three crops, one plant and two ratoons:

SUMMARY OF RESULTS FOR THREE CROPS.

Variety	1917 Crop 14 Months Plant			1918 Crop 14¾ Months Ratoons			1920 Crop 18 Months Ratoons			Average Three Crops		
	Cane	Q. R.	Sugar	Cane	Q. R.	Sugar	Cane	Q. R.	Sugar	Cane	Q. R.	Sugar
H 460	56.8	8.41	6.76	60.9	8.78	6.94	87.4	8.99	9.72	68.4	8.76	7.81
H 466	50.0	8.87	5.64	56.8	8.33	6.83	89.7	9.54	9.40	65.5	9.00	7.29
H 465	44.5	8.02	5.55	54.7	7.47	7.31	70.2	7.80	8.99	54.8	7.53	7.28
H 425	41.3	8.51	4.86	50.5	8.34	6.05	86.2	9.13	9.42	59.4	8.78	6.77
H 427	35.5	7.73	4.60	51.2	7.93	6.45	73.4	7.99	9.18	53.4	7.92	6.74
Badila	45.5	7.91	5.75	40.1	7.89	5.08	78.7	8.57	9.18	52.9	7.93	6.67
H 463	46.4	8.33	5.57	54.2	8.19	7.65	63.2	10.09	6.26	54.6	8.41	6.49
H 431	32.5	8.12	4.00	44.5	8.16	5.48	75.5	7.93	9.52	50.8	8.03	6.33
H 416	28.3	8.35	3.39	49.6	8.13	6.11	76.8	8.38	9.15	51.6	8.29	6.22
H 411	48.1	8.33	5.78	48.0	10.01	4.81	64.2	9.57	6.71	53.4	9.25	5.77
H 409	26.8	9.16	2.93	47.2	8.64	5.50	72.4	8.62	8.40	48.8	8.69	5.62
H 464	46.5	9.03	5.15	49.6	8.21	6.04	57.8	10.28	5.62	51.3	9.19	5.60

In the above list H 460 leads in the average production of sugar for the three crops, having been fairly consistent throughout.

H 431 and H 425 are worthy of note in that they seem to be improving. H 431 was tenth in order of sugar production in the plant crop in 1917, while in this year's harvest it was second; H 425 was eighth in 1917 and third this year.

H 416 is also much better now than it was in the first two crops. This would indicate that these canes have good ratooning qualities.

H 427 and H 465 deserve attention for their good juices. Both of these canes are consistently better than Badila in the quality of their juices.

J. A. V.

Observations on Applications of Mud Press Cake.

The following analyses of mud press cake, based on dry weight, have been made for experiments where this material was being tested:

	% N.	% P_2O_5	% K_2O	% Moisture
Paauhau Exp. 13 (1917).........	2.40	5.88	0.27	13.72
Paauhau Exp. 14 (1919).........	2.63	9.05	0.14	27.80
	2.59	7.71	0.21	58.00
Wailuku Exp. 7.................	1.16	6.96	0.31	55.92
Oahu Sugar Co. (Waipio Exp. F.).	1.41	4.41	0.46	74.18
Average	2.04	6.80	0.28	
Lbs. per Ton of Dry Material.	40.80	136.0	5.60	

We note from the above the amounts of nitrogen, phosphoric and potash in the mud press cake vary greatly in these samples secured from three widely-separated localities.

Considering the fact that all plant food represented is in an available form, we have a good fertilizer, and if we apply about 10 tons of press cake (60% moisture) per acre, we are giving the cane 163 pounds of nitrogen, 544 pounds of phosphoric acid, and 22 pounds of potash per acre. For most places this should satisfy the plant food requirements of cane.

In the following table are given the amounts of nitrogen, phosphoric acid and potash that would be contained in 5, 10, 20 and 30 tons of mud press as reported above, assuming the mud press to contain 60% moisture when applied:

Amount of Mud Press	Pounds of Nitrogen	Pounds of Phosphoric Acid	Pounds of Potash
5 tons	82	272	11
10 "	163	544	22
20 "	326	1088	45
30 "	489	1632	67

J. A. V. and W. P. A.

Destroying Nut Grass.*

Mr. F. Lan. Nott ("The Grange," Woongarra, Bundaberg), in reply to an inquiry by the Director of the Experiment Station (Queensland) concerning a coccid insect attacking nut grass, wrote as follows:

"When starting the cultivation of cane on my farm, I was greatly troubled with nut grass, which was distributed over about 30 acres, which thrived in ratio to the cultivation, and I experienced great difficulty in raising payable crops of cane. Usually, the crop had to stand over and thus become a two-years' crop. This, I may say, always happened in what is known as the plant crop, but ratoon crops were usually cut at twelve to thirteen months. Naturally, the loss through this delay, compared with crops on the same quality of land free from the weed, was very great; also, the amount of extra cultivation cost was severely felt.

"I had come to the conclusion that I would throw the land out of cultivation, but at last obtained some coccid insects on some nuts from a locality where I had heard that a trial (and a failure) had been made for the eradication of this pest by this means.

"I started with spreading 'diseased' nuts at about 8 yards apart over four-fifths of an acre, and allowed these to remain without disturbing them for two months, when the land carried a beautiful crop of nut grass. I then plowed it up and harrowed it to better distribute the parasite (which had considerably increased in numbers), and planted the land with lucerne, and watched the progress of the disease.

"Naturally, when the lucerne grew vigorously, little nut grass was to be seen. However, from observation I was satisfied that the parasites were behaving well. After about fifteen months I removed the lucerne, and expected to see, at least, a considerable return of the nut grass plants, but very few came, and those few were all weak and eventually disappeared.

"As control, I had the adjoining land on three sides of a rectangular plot, and on the eastern side was a road, which effectually prevented the parasite from extending in that direction, but they spread to the south side.

"Since that time I have had splendid results from the treatment, and am sure that, if carefully applied, the results are well worth the time spent on the trial The following are the cardinal points to be observed:

"1. See that there is a good crop of nut grass.

* Queensland Agricultural Journal, Nov., 1919, p. 223.

"2. Distribute the coccid as evenly as possible.

"3. After distribution, plant a cover crop, or, at least, do not disturb the soil. This last remark is important, as by cultivation the coccid is killed before the nuts.

"Up to the present I have eradicated the pest on 20 out of the 30 acres, the time taken being four years from the commencement. The most difficult part is to stop the plant from spreading around the fringe or boundary of the land, as the coccid cannot travel from one patch across a wide gap to another.

"During the first two pears I kept a sharp lookout, as the remedy might have taken to other and desirable plants, but so far I have not seen it live and generate on any other plant. I do not think there would be any danger by its introduction, nor should there be any trouble in introducing the coccids, as they can easily be transported on the nuts.

"I know of one place in Queensland and one in New South Wales where it was tried, and both of these would report failures—failures which, in my opinion, were caused by expecting the insect to work miracles and by a want of knowledge of the life history of the insects. My experiments were carried out on red volcanic soil of a heavy nature, with a climate usually dry in spring. From the beginning of operations to the killing out of the nuts should not take more than three years. When the insect has been distributed, allow the land to go into grass, or put in a cover crop, but do no after cultivation for the time mentioned."

[H. P. A.]

Experiments in the Eradication of Nut Grass.*

This plant (*Cyperus rotundus*) is one of the worst weed pests in the Hawaiian Islands. It spreads by seeds when these are allowed to form, but aside from seed production, it produces underground corms up to 12 mm. diameter in size which possess the ability to reproduce the plant under remarkably adverse conditions.

An attempt was made to eradicate nut grass by cultivating sufficiently to prevent any growth above ground. The field was harrowed or disced about once every three days, depending on the amount of rainfall and resultant rate of growth. The experiment was started August 10th and continued to December 6th of the same year, when continued rains made the field in question so muddy as to make continued cultivation impracticable. From time to time thirty representative nut-grass corms were selected and weighed to note whether preventing growth above ground was actually reducing the size and hence the vitality of the corms.

Date	Weight of 30 Nut-grass Corms	Average Weight of One Corm	Days Since Beginning Clean Culture
August 10	27.3 grams	0.91 gram	0
October 18	12.9 "	0.43 "	69
December 6	9.0 "	0.30 "	118

* College of Hawaii Bul. No. 5.

At the time it was necessary to discontinue the experiment the growth of the grass showed that there was still plenty of vitality left in the corms. However, reduction to one-third of their original size in 118 days shows the effect of the starving process.

On February 10th, 64 days after cultivation had been discontinued, thirty corms selected from the same field showed an average weight of 0.74 gram each, indicating the rapidity with which food material is stored in corms when the tops are allowed to grow unchecked.

The corms exposed to air and sunshine lose about 30% of their weight in three weeks. An average corm as taken from a reasonably dry soil contains 53% moisture. Four nut-grass corms placed in good soil and allowed to develop produced plants two feet high in 42 days.

Six nut-grass corms in a soil that was flooded with water for 32 days produced strong, vigorous shoots four days after they were taken out of the water-logged soil. [W. P. A.]

The Kudzu—An Interesting Legume.

The Kudzu plant, a legume imported from Japan, was recently found locally by Mr. E. J. Mooklar in a Chinese garden on King Street, Honolulu. We are planting this legume in Manoa in order to supply cuttings to those who may wish to give it a trial. The Fiji Planters' Journal.* under the heading, "Kudzu, a Great Fodder Plant", describes it thusly:

"This plant is a native of Japan, where it is a leading crop, and is highly commended by the United States authorities. This is a perennial vine, and its numerous merits compared with lucerne, which is styled the 'King of Fodder Plants', are many. It succeeds in any class of soil, if drained; does not require any fertilizer; it rapidly enriches poor soil; it does not require to be cut at a certain time to save it. It will transform poor soil, or barren hillsides into profitable use; it makes good permanent pasture and it is not injurious to stock at any stage—either green or dry—and when fed to cows it will produce more and richer milk than any other single feed, as it is more nutritious than either lucerne or bran. It is said that in the United States it has produced four cuttings of two and a half tons each per acre annually. It is very drought-resistant, as it roots deeply, and the vines cover the ground with foliage which acts like mulch and conserves moisture. It is also said that land planted with Kudzu soon becomes like the rich soil that has recently been cleared from the virgin forest, and it becomes richer each year through the large quantity of nitrogen deposited therein. It should be cultivated in rows eight feet apart the first season, after which it will require but little attention."

From Bailey's Encyclopedia of Agriculture† we quote this account of the "Kudzu Vine":

* B. Harrison, F.R.H.S., Burringbar, N. S. W., Vol. V, No. 47, p. 182.
† Vol. V, p. 2856.

A Kudzu Plant, grown in a Honolulu garden.

"PUERARIA (M. N. Puerari, botanist of Geneva). LEGUMINOSAE. P. Thunbergiana. Dolichos japonicus. KUDZU VINE. Perennial, with large tuberous starchy roots, making a vigorous growth of slender hairy, twining stems. A hardy vine remarkable for the great rapidity of its growth, and most useful for covering arbors and verandas. It is also used as a forage plant. From a well-established root, vines will grow 40-60 feet in a single season, producing a profusion of very large leaves. In the north the plant dies to the ground in the winter, but in the south the top becomes woody. The large fleshy root assumes most curious shapes, the main branches often being 4-5 feet long. Georgeson writes of the plant in Japan: 'The roots are fleshy and yield starch of excellent quality; the tough fiber of the inner bark is manufactured into a sort of cloth which combines fineness with remarkable strength; and in certain situations the vine is unparalleled for ornament and shade.' Propagated by division of the roots, or by seeds when they can be had; also by cuttings." [H. P. A.]

Manufacture of Nitrate of Lime in Norway.*

While the principle of the process used in Norway for the production of nitrates from atmospheric nitrogen is generally understood, it would be difficult without actual inspection to form anything like an adequate conception of the magnitude of the industry. A total of 300,000 to 350,000 horsepower, rendered available from waterfalls, is now in use in the synthetic manufacture of nitrates. The first factory was established at Notodden in 1905, but Rjukan, where works were also opened in 1911, and considerably extended after the commencement of the war, is now the chief center of the industry. A few practical details about the manufacture of nitrate of lime at the latter place may serve to convey some idea of the nature and proportions of the enterprise.

Rjukan I, as it is called, to distinguish it from the newer works there, is in reality the largest water-power station in the world (140,000 horsepower). The current from there is conducted to the furnace-house through 60 cables of a length of three miles each. By means of blowers 1000 million gallons of air are at Rjukan driven through the electric furnaces every 24 hours. The heat in the furnaces, exceeding 3000° C., brings about a combination of the nitrogen of the air, resulting in the formation of nitric oxide (NO). These hot gases (800° C.) are used as fuel in large steam boilers, where the temperature is reduced approximately to 250° C. By water-coolers the heat of the gases is further reduced to about 50° C.

The subsequent retention of the gases for some time in large oxidation tanks results in the transformation of nitric oxide (NO) to nitrogen dioxide (NO_2). The gases are next conveyed through three granite towers, 23 meters high, and filled with quartz sprinkled with water. This operation causes the absorption of the nitrogen dioxide by the water with the production of weak

* The American Fertilizer, Jan. 17, 1920.

nitric acid (30 per cent). This acid is then passed over limestone, and a solution of nitrate of lime is thus obtained.

The weak solution of nitrate of lime is next concentrated by evaporation until it contains 13.1 per cent nitrogen. The liquid nitrate being now thick is passed over revolving cylinders, which are internally cooled; the nitrate is here rapidly solidified and is taken off in leaves. The leaves of nitrate are then granulated in small mills. From high silos the nitrate in the finished state is filled into barrels of 100 kilos net weight. At Rjukan alone the normal daily production is 2000 barrels.

It may be of further interest to mention that Rjukan, where the barrels themselves are made, possesses actual facilities for making 5500 and packing even 6122 barrels daily. What this means may be illustrated by the fact that the staves required for this number of barrels would, if placed end to end, extend over 80 miles, and the iron for the hoops over 20 miles. By working at full pressure it is possible with the existing facilities to fill a cask every one-sixth of a second. [J. A. V.]

Ratooning in Australia.*

A method of ratooning sugar cane used at the Mackay Sugar Experiment Station, in Australia, has given large yields of ratoon crops. It is as follows:

It is believed that the best method of securing large yields of ratoon cane is to adopt the following procedure: Immediately the trash is burnt, open up the middles of the rows to a depth of 9 inches with the swing plow; next subsoil these two furrows so that a further depth of 6 inches in thoroughly stirred. Next plow away from the cane rows on to the middles and again follow with the subsoiler. By this means the whole of the ground between the rows has been moved and stirred to a depth of 15 inches; and the benefit to the ratoons in thus breaking up the hard ground and letting in air and sunlight is difficult to overestimate. Subsequent shallow cultivation with broad hoes should now be practiced frequently, in the same manner as recommended for the plant crop.

The results obtained at the Experiment Station, due to this method of cultivating ratoons, are detailed in the table below:

* Queensland Agricultural Journal, Dec., 1919.

Crop	Yield of Cane per Acre where the ground between the rows was plowed and subsoiled	Yield of Cane per Acre where the ground between the rows was only plowed to 8 inches
	English Tons	English Tons
First Ratoons	38.9	27.0
Second "	31.3	19.2
Third "	20.4	9.91

These experiments were not fertilized.

[W. P. A.]

Rats Killed by Fright.*

VARNISH AS DEATH-TRAP.

As the result of experiments carried out by his department, Dr. Howarth, Medical Officer for the City of London, is now able to recommend varnish as one of the most effective ways of destroying rats on a large scale.

In an interview yesterday, Dr. Howarth explained that the substance used is strong lithographic varnish. It should be warmed by heating the container holding it, in boiling water. When warm the varnish will run, and in this condition it should be spread one-sixteenth to one-eighth of an inch thick on pieces of strawboard or fairly thick cardboard measuring about 15 in. by 12 in. A margin of about an inch should be left clear of varnish, and the bait placed in the center of the board where it will adhere to the varnish. The traps should be placed along the rat runs, or near the holes. They remain effective for about four days, when the old varnish should be scraped off and a fresh layer applied.

"We are continually faced with the rat problem in the City," said Dr. Howarth. "We first discovered varnish being used in a place in Fenchurch Street. Since then we have experimented very successfully. In some cases we have had 'bags' of 60 and 80, and I can recommend it as an excellent means of ridding a place of rats. Disappointments arise chiefly through the varnish being too weak or too 'tacky.' This allows the rats to move on it with impunity. We are endeavoring to meet that possibility by standardizing the quality of the varnish. People should continue to put down the boards so long as they are catching rats. It does not matter if a board has had a dead rat on it. They should just remove the body and put on more varnish.

"The varnish is not poisonous, and a coroner's jury would probably ascribe death to natural causes following a shock," continued Dr. Howarth. "I think that the rats die of fright. Once their tails stick their doom is sealed. They never

* From the London Times.

get near the bait. They get their feet in the varnish and the more they struggle the faster they stick. Rats caught during the night are always dead in the morning, and it is a very remarkable thing that if two rats get on to the varnish together one of them kills the other. Evidently each thinks that the other is holding him. Then there is a battle royal, and we find one with its neck bitten through. As to the cruelty of it, we cannot afford to waste sentiment, and it is certainly not as cruel as phosphorous poison, which takes about four hours to kill."

Dr. Howarth produced a couple of the traps with the victims of his experiments. In each case the bait was untouched, the rats having stuck immediately they touched the varnish. The Public Health Department at the Guildhall is ready to furnish information and to recommend manufacturers for supplying the varnish. [H. P. A.]

Plant Food.*

It might be well to begin by defining a few terms. First, then, what do we mean by "Plant Food"? According to the Standard Dictionary, food is defined as "any substance that, being taken into the body of animal or plant, serves, through organic action, to build up normal structure or supply the waste of tissue; nutriment * * *" As a second definition of "food," we find—"that which increases, keeps active, or sustains." Turning to "nutriment," we find it defined as "that which nourishes; that which promotes the growth or repairs the natural waste of animal or vegetable organisms; food." This last definition would seem to include as plant food, light, air, water and heat, as well as the so-called elements of plant food, which we ordinarily think of first when using this term. It seems to me a significant fact that we read in the account of the creation of Genesis, that God first created light, then air (firmament), then water and land, then said, "Let the earth put forth grass, herbs, yielding seed, and fruit trees bearing fruit after their kind, wherein is the seed thereof, upon the earth: and it was so." Then He set the lights in the firmament, among them the sun as a source of light and heat, and to control the seasons. The term "chemical requirements of the plant" would then seem to properly include: light, heat, air, water, and the so-called "elements of plant food," or plant food elements.

As man can not generally control the light, heat and air necessary for most cultivated plants, and in many cases not even the water, we shall confine our attention to a brief consideration of the plant food elements, considering the air and water only in so far as they furnish these elements.

"Elements" and "Substances."

Now as to the meaning of the term "element." Sir Robert Boyle (1627-

* Dr. R. N. Brackett, Clemson College, Short Course for Fertilizer Salesmen. From Commercial Fertilizer, Dec., 1919.

1691) defined an element as "the constituent of a compound substance which can be readily prepared, but which can not be further decomposed." Lomonossov, a Russian author, statesman, and chemist (1711-1765), in 1741 first drew a distinction between simple and compound substances, according to Dr. Alexander Smith, one of the leading chemists of the United States; a distinction more accurately drawn by Lavoisier, the great French chemist, in 1789.

By the way, I may say that the term "substance" is used by the chemist to designate a homogenous simple or compound material. Lomonossov is also credited with the enunciation of the first and most fundamental law of chemistry: "Every material can be described as being composed of one substance, or as being a mixture of two or more component substances, each of which has a definite set of specific physical properties."

Dr. Smith himself defines an element as one of the simple forms of matter, either free or in combination, and states that "simple or elementary substances are substances which we are not able, at will, to decompose into other substances, or to make by chemical union from other substances."

We now know about 83 such elementary substances. Taking the atmosphere, all terrestrial waters, and the earth's crust, so far as it has been examined, F. W. Clarke has estimated the plentifulness of the various elements. The first twelve, with the quantity of each contained in one hundred parts of terrestrial matter, and constituting together 99 per cent, are as follows: Oxygen, 49.85; silicon, 26.03; aluminum, 7.28; iron, 4.12; calcium, 3.18; sodium, 2.33; potassium, 2.33; magnesium, 2.11; hydrogen, 0.97; titanium, 0.41; chlorine, 0.20; carbon, 0.19.

Thus oxygen accounts for nearly one-half of the whole mass; silicon, the oxide of which is when pure quartz and in less pure form constitutes ordinary sand, makes up one-half of the remainder. Valuable and useful elements, like gold, silver, sulphur, and mercury, are among the less plentiful, which, all taken together, furnish the remaining one per cent.

Essential Elements.

The following 14 elements are found to be essential in building up the structure and in making good waste of animals and plants: oxygen, hydrogen, carbon, nitrogen, sulphur, phosphorus, gallium, magnesium, potassium, iron, sodium, chlorine, silicon, fluorine. To these is sometimes added manganese, but it is doubtful whether the last four and manganese are necessary to plant growth, so that the plant food elements might be restricted to 10. About 98½ per cent of the plant consists of hydrogen, oxygen and carbon, based on its entire composition. The dry matter of plants contains from 1½ to 7 or 8 per cent of ash. The elements found in the ash are, calcium, potassium, magnesium, sodium, iron, phosphorus, sulphur and silicon, sometimes manganese and aluminum, and occasionally other accidental constituents. The amounts of the ash elements is so small when compared with the composition of the whole plant, that at one time, they were considered accidental and unessential, indeed, until Liebig proved that they were essential to the growth of plants. We now know that the chemical requirements of the plant involve and include light, heat, moisture, all of which are intimately connected with the good physical condition of the soil, as well as

favorable biological conditions, together with an adequate supply of all the above-named elements in forms available for use by the plant.

Elements taken from the air: The composition of pure, normal, dry air is usually given as: By volume, nitrogen, 78.12; oxygen, 20.941; argon, 0.937; by weight, nitrogen, 75.539; oxygen, 23.024; argon, 1.437. But the atmosphere is a complex mixture of oxygen, nitrogen, carbon dioxide, argon, moisture, which are always present; oxides of nitrogen, and of sulphur, and their acids; ammonia compounds, dust, both organic and inorganic. While necessary to the germination of seed and the growth of the plant, it is not believed that the free oxygen in the atmosphere is used by plants in building up their tissue, but that they obtain their oxygen and hydrogen largely from water, and hence may be said to get these elements in part from the atmosphere, or air.

We know also that only a few plants, notably the legumes, are able to utilize free nitrogen in making their growth. From the carbon dioxide in the air, although it occurs in only very small quantity, about three or four parts in 10,000, except of course in the soil air, and in the air over fields where organic matter is undergoing decay, the plant is believed to obtain all its carbon, the oxygen of the carbon dioxide being returned to the air, for the most part, if not entirely. We do not know the function of the argon.

During thunderstorms some of the oxygen and nitrogen combine and form oxides of nitrogen, which in turn react with the water to form the nitric acid and nitrous acid, which is brought down to the ground in rains, often combined with ammonia resulting from the decomposition of organic matter containing nitrogen, and in this way plants certainly obtain some of their nitrogen. They also obtain some nitrogen and sulphur from sulphate of ammonia produced in the burning of coal. They may, and no doubt do, also obtain some other elements from the dust carried in the air.

What Plants Obtain from Air.

We may sum up the elements of plant food obtained from the air, I think, in the statement that they obtain all their carbon, and some of their hydrogen, oxygen, and nitrogen, and sulphur.

Elements taken from the soil: The ash elements—calcium, magnesium, potassium, sodium, iron, phosphorus, sulphur and silicon and manganese are for the most part obtained directly from the soil, as is also the greater part of the nitrogen. These elements must be present in the soil in sufficient abundance, and in forms which are not injurious to the plant, and which are soluble in water, or in the soil solution, in order that the plant may make a normal growth. Experiments prove that no element can replace another in plant growth, even where the elements are as much alike as sodium and potassium. The maximum yield of a crop is conditioned by the minimum present of the essential element as compared with the needs of the crop. Sodium, silicon, chlorine and manganese are usually regarded as non-essential ash ingredients, though always present in plant ash, when plants are grown under the usual conditions.

Forms of combination from which plants obtain their essential elements: With the exception of nitrogen in the growth of legumes, it may be said that plants do not take up the elements themselves, but in combination with other

elements in the form of various compounds. Carbon from carbon dioxide; hydrogen and oxygen from water; nitrogen from nitrates of sodium, calcium, magnesium, and potassium, sulphate of ammonia and other ammonia salts, amino-acids, and urea, though chiefly from nitrates and ammonia salts; sulphur from sulphates, especially calcium sulphate; phosphorus, from phosphates of calcium especially; potassium from chloride (muriates), carbonate (as in wood ashes), sulphate, nitrate, and possibly silicate; calcium, from slacked lime, ground limestone (carbonate of lime), land plaster (gypsum), phosphate of lime, and nitrate of lime; magnesium, from the carbonate, sulphate and nitrate and chloride, and possibly phosphate; iron, from oxides, carbonates, chiefly. (Organic forms of nitrogen, including "cyanamid," which are readily transformed into nitrates in the soil, are also used in large quantity, of course.) These fasts account for what we may call "natural filler." Even could we purchase the elements necessary for plant growth—were they cheap enough—they would be of no use as fertilizers. (Examples: potassium; calcium; phosphorus; nitrogen; sulphur—noting exception, sulphur, soil and manure—Lipmann. Experiments.) But there is undoubtedly rapidly coming a time when we shall use more and more concentrated sources—e. g., "Ammophos"; ammonium nitrate; possibly urea; double superphosphate, etc.

Soil Analysis.

For total plant food, including lime requirements, organic matter and essential plant food elements above enumerated. Gives absolute data for comparison of soil types. Gives potential, or reserve supply of plant food. Value and limitations. "The total amount of plant food present in the soil is surprising, in view of the fact that it is often difficult to maintain a satisfactory yield of crops." Composition of some American soils (see Hart-Tottingham, page 70). Most soils are comparatively low in total nitrogen, phosphorus and sulphur, but generally contain large reserves of potassium, calcium and magnesium and iron.

Temporary supply of plant food, measurement of amount of plant food supposedly of immediate availability to plants. Many attempts to determine by weak solvents, or by dilute solutions of strong solvents. None of these methods are general or universal guides to the manurial requirements of a soil or crop. Soil analysis are not a measure of crop needs, nor a guide to the relative amounts of fertilizers to be added.

Physical analysis of soils and their value, coupled with a knowledge of the crop-producing power of such types.

Plant Analysis.

When Liebig showed that the plant ash constituents were absolutely essential to plant growth, and not accidental as once supposed, there grew up the idea that it was only necessary to analyze the ash of the plant and add the amounts of the plant elements thus removed by an average crop, in order to maintain the production of good, average, normal crops. This was called the mineral theory of fertilization. It was proved by experiments at the Rothamsted Experiment Station in England that plants must have added nitrogen, as they could not obtain sufficient for their growth from natural sources. It has also been demonstrated that the analysis of plant ash does not furnish a safe guide

to the amounts of fertilizing elements to be added, is not a safe index to the actual needs of the crop, since the plant ash constituents taken up by the plant vary with the season; abundance of plant food available, vigor of the plant, the ability of the plant to get the different elements of plant food and no doubt other factors, including, of course, the reserve supplies of plant food in the soil.

The analysis of the whole plant is valuable as furnishing useful information as to the total amount of plant food removed by an average crop, under normal conditions, with the limitations above cited as to plant ash. Such analysis gives at least an approximation to the needs of the plant, especially when the composition of the soil is also known, but with the limitation that we are unable to determine the amount of available plant food in the soil with an exactness. Perhaps to be on the safe side, we should add the amount of ash elements plus the nitrogen indicated by the analysis of the whole plant, ignoring the plant food contained in the soil itself.

It must be apparent that neither the analysis of the soil, nor of the plant, nor of both taken together, can furnish the necessary data for the application of plant food to meet the actual needs of the plant in any given case. Hence it has been concluded that the only way of measuring crop needs for plant food is to make field experiments, which is, of course, a slow process, requiring several years in order to be able to draw really valuable conclusions.

[J. A. V.]

Crystallization of Sugar from Its Aqueous Solution.*

By Dr. H. C. Prinsen-Geerligs.

Many a time phenomena of retardation and acceleration in the crystallization of sugar have been observed as well in the practice of the sugar-house as in the scientific sugar laboratory, which up to now have remained without explanation. Every technical sugar man knows that when boiling sugar juices in the vacuum pan sugar sometimes crystallizes very rapidly, when, on other occasions, all kinds of artifices have to be employed to bring the sugar to the crystallizing point. It is also a recognized fact that in the cane sugar industry the formation of grain in the pan goes much more smoothly than in the beet sugar industry, even so that the formation of secondary, so-called "false grain" is much more to be feared there than in the sister industry. It is true that these phenomena need not be ascribed to some property of the sucrose itself, but may be brought along by the nature of the non-sugar bodies accompanying the sucrose in the syrup. We know that crystallization takes place much earlier and better in pure syrups than in impure ones, even if the proportion between sucrose and water and also the temperature and vacuum are the very same. Moreover, it may be that the more rapid crystallization in cane sugar syrups is a consequence of the different reaction,

* Louisiana Planter, Vol. LXIV, Jan. 10, 1920.

which usually is alkaline in beet sugar juices and neutral or acid in those of the cane.

But apart from the influence of the non-sugar there are cases in which, under apparently just equal circumstances, sucrose at one time crystallizes rapidly from its pure aqueous solution, while in other cases it appears very slowly in crystalline form, while as yet no reason has been detected to explain these facts.

We found in our many experiments on crystallization of sucrose from genuine and artificial molasses that sugar crystallizes much more rapidly in case the solution had been heated to a relatively low temperature and during a short time than when the mixture had been heated to higher temperatures or during a longer period, and we attributed to that property of sugar the fact that in well-equipped sugar houses, with their rapid working up of the juice at low temperature in the vacuum apparatus, crystallization of sugar takes place much easier than in laboratory experiments.

Recent experiments by "Van der Linden," published in Archief voor de Suiker Industrie in Nederlandsch Indie, 1919, 1517, stated that a molasses which, on cooling, separated a great deal of minute sugar crystals, failed to do so when after re-dissolving these again by heat the same molasses was cooled down a second time in exactly the same way.

We see from these instances that, although of course the non-sugar, present along with the sucrose in the liquid, exerts its influence on the rapidity with which the sugar crystallizes out, yet besides there exist factors which have also an influence of their own on the rapidity of crystallization of sucrose, the nature of which is still unknown to us.

In Chemisch Weekblad, 1919, page 1210, Van Ginneken published an article on the crystallization of sucrose from supersaturated solutions in which, among others, the subject considered here has been thoroughly ventilated and in which the experiments are being extensively discussed. Every one of these experiments are made with mixtures of pure sucrose and pure water, thereby excluding all influence of non-sugars and only allowing circumstances of temperature, concentration, time and intensity of movement of the solutions to enter into account.

We know that the study of crystallization of sucrose from its aqueous solution is rather difficult because of the viscosity of the syrups and the property of sucrose to form very easily supersaturated solutions, which sometimes take considerable time to come down to their permanent state of sugar content, and that is why these phenomena offer such great trouble to be examined properly.

Van Ginnken went to work as follows: Portions of 12 to 13 grammes of refined sugar were carefully weighed into test tubes of 18-20 millimeters diameter and 156 millimeters length; according to the concentration to be studied. Quantities of 2-3 grammes of water were added and the tube sealed by the blast-pipe, thereby leaving a length of tube of about 130 millimeters. The tube was fixed to the perpendicularly horizontal axle of a stirrer moving in a heated oil bath to which it was attached in such a way that during the movement of the axle the contents constantly flowed from one side of the tube to the other one, thereby insuring steady and full homogeneity. The temperature of the oil bath was kept constant usually at 110 degrees C. and sometimes at 130 degrees or 135 degrees C., and the tube remained exactly at these temperatures during the

time necessary to occasion the sugar to be dissolved, which time was in most cases fixed at 30 minutes. After that period the tube was rapidly removed from the oil bath and transferred to a water-thermostat, which was the exact copy of the oil-bath and in which the temperature and the number of revolutions of the stirrer were kept constant during the whole duration of the crystallization experiment. The temperature of the water bath was kept at 80 degrees C., and it remained constant with fluctuations of no more than 0.2 degree to either side. This method of operating guaranteed solutions of an absolutely certain constitution and of a constant degree of supersaturation, cooled down and kept in a constant movement at a constant temperature with a rather satisfactory degree of constancy in the intensity of movement during crystallization.

The tubes were observed during their cooling time and the moment of apparition of the first crystal was noted, the stirring at the temperature, chosen for the experiment, continued and the moment was noted again when, by ocular inspection, the contents of the tube might be considered to have reached their maximum crystallization.

A few figures intended to give some notion of the time required may follow here: If a mixture of 84½ per cent of sucrose and 15½ per cent of water is heated in the sealed tube for 30 minutes in the oil-bath at 110 degrees C. and then transferred to the water-bath of 80 degrees C. and revolved there 33 to 35 times per minute the first crystal will probably appear after three-quarters of an hour, but it may also be that it will be ten hours before the first crystal is visible. The former case, however, is the most common one and the retardations will be considered later on.

The experiments by Van Ginneken lead to the following conclusions:

1. It is possible to state by the above-mentioned method the inclination of the formation of the first crystal and next in a somewhat approximative way the rapidity of crystallization after the formation of the first crystal.

2. The time necessary for the formation of the first crystal is much more than that required for the next ones.

3. Previous history of the solution and, in some cases, even that of the solid sugar has an influence on the inclination of formation of crystals.

In the first place series of experiments were made in order to ascertain the rapidity of formation of first crystals in sugar solutions of varying concentration at 80 degrees C., and though, as we mentioned before, the individual results do not show a fine accordance, it was proved by the majority of experiments that the most favorable concentration for the formation of crystals at 80 degrees C. is found between 83½ and 84½ per cent of sugar, or just as has been advocated by Claassen from his practical experiments as the optimum concentration of syrup to start graining in the vacuum pan. After crystals have been once formed, the further ones appear at the same temperature and concentration with much greater rapidity. If, therefore, the pan-boiler has formed his crystals in the syrup in the pan, he will see them increase in number, in case he keeps concentration and temperature at the same level as before. This has to be taken into consideration in practical working, for, as soon as one has the necessary amount of small crystals in the liquid, it will be necessary to stop the formation of new

ones so that a dilution of the syrup in the pan may not only be harmless, but even desirable.

It will be necessary to prevent formation of secondary crystals after the primary ones are present in their useful number, which have to grow in order to form a proper massecuite, and, therefore, it will be very useful to keep the syrup after the graining at such a concentration that formation of new crystals is as difficult and slow as possible. The experiments showed that under 80 per cent of sugar the inclination of formation of new crystals is so small that it may be considered as extinct. Over 81 per cent the inclination is higher and formation of secondary grain is possible under the circumstances prevailing in practical work. As, however, it is not feasible to keep concentration during boiling so low as 81 per cent, one is obliged to use higher concentrations, and that is why in sugar-house work circumstances will never be so that formation of secondary grain could be rendered absolutely impossible.

It is further the question why the first crystal is formed so much more slowly than the next ones, and in order to explain this fact Van Ginneken considers two possibilities. The first one is the autokatalytic action of already formed crystals on sucrose molecules in their vicinity, and the other the formation of large complexes of sugar molecules which have been driven apart by the heating to 110 degrees C. and now are apt to combine again at the lower temperature until they condense into crystals. This process will take some time, and then it is very obvious that soon after a few complexes have become so far condensed as to build crystals, others are very near that point and consolidate very soon afterwards.

Van Ginneken believes the two causes to coincide and the katalytic one to be the leading one.

Under autokatalytic action he understands a kind of action of a sugar crystal on still dissolved molecules which by that action are encited to form another crystal, which in its turn exerts that action on other molecules, as long as all the sucrose, existing in supersaturated state, has been combined in the crystallized form. If once a crystal is present, the others will arise very soon, and it resulted from those experiments in which on purpose the dissolution of the sugar in the oil-bath was conducted in such a way as to leave one or two crystals undissolved, the formation of further crystals in the water-bath occurred much earlier than in the ordinary cases, when all of the sugar had been dissolved, leaving no crystal to start the action.

A second proof for the katalytic action is, according to Van Ginneken, the fact that sometimes the first crystal delays its apparition during a very long time, but that notwithstanding this, the end of the total crystallization is reached after the normal time. It is difficult to believe that in such a case hours are needed to form the first crystal by condensation from smaller complexes, but that suddenly after the first visible condensation all the other complexes join to form crystals at once.

But, anyhow, this possibility may not be excluded totally, for it is not to be denied that in every case the breaking up of large complexes into smaller ones and the reformation of these units into larger and larger ones which at last form crystals on cooling must exert its influence. If not, the fact, already mentioned

in the beginning of this paper could not be explained, viz: that the previous history of the solution and even of the solid sugar plays an important part in the rapidity of crystallization of sugar from its aqueous solutions.

A great series of experiments showed Van Ginneken that heating of the solution in the oil-bath to 130 degrees C. retarded the formation of the first grain considerably over heating to 110 degrees C. and that, notwithstanding the fact that no decomposition of sugar could have been made responsible for this phenomenon.

If the contents of a same tube were made to crystallize repeatedly, after being re-dissolved again in the way indicated, the formation of the first grain became slower every time. Further, it was observed that in such cases re-dissolution became slower and slower too, while one might be apt to believe that the repeated crystallization could render that formation easier.

Finally, the previous history of the sugar itself appears to be of some importance. Van Ginneken made a great many experiments with pure refined sugar from the refinery, but wanted to repeat these with pure sucrose. To that end he precipitated a concentrated watery solution of refined sugar with alcohol, washed the fine crystals, thrown down, with alcohol and ether, evaporated the etheral fluids and used the dry, pure sucrose in his experiments. He found that the formation of the first crystals took much longer time than in his experiments with the refined sugar, for which he could not account.

He mixed minute portions of impurities such as might be present in refined sugar with the pure sucrose in order to see if these were the reason of a better crystallization, but without avail. On the other hand, he ground refined sugar to a fine powder and used that in order to know if, perhaps, the fine crystalline state had exerted some influence, but the finer refined sugar did just as the coarse one and not as the pure precipitated preparation.

We are led to assume that the pure sucrose is precipitated by the alcohol in a configuration deviating from the one in which it crystallizes from its aqueous solutions. On using the same pure sucrose for further experiments after it had stayed during a few months in a bottle, the behavior in the tubes was identical with that of the refined sugar, so that perhaps the deviating configuration has become normal after some time.

At all events, the experiments show distinctly that the previous history, both of the solution and of the solid sugar, have an influence on the inclination of the sucrose to combine into crystals, and it is very probable that the sometimes rather large differences in the results of two experiments made in apparently exactly the same way, may be traced back to some factor in the previous history of the substance used, of which we have as yet no knowledge

It is very important for the proper working of the boiling process in the vacuum pan if these factors could be ascertained and investigated, and in that case we believe that the method used by Van Ginneken may shed new light on the subject, so that continuation and repetition of these experiments will be of a great value for our industry. [W. R. M.]

Sugar Cane Culture in South Africa.*

Climate for Cane.

Sugar cane is essentially a tropical plant, and though it will grow in the Midlands of Natal for fodder purposes, it fails as a sugar producer. Being tropical in its natural habitat, regions planted with cane must be frost free. They must also be moist, and with the moisture there must be heat.

The climate of Zululand is more suited for cane culture than the climate of Natal, due to its greater humidity and heat, whilst the Natal coast belt enjoys a rainfall of 35 inches to 40 inches on an average. The best cane-growing parts of Zululand and Portuguese East Africa have an annual precipitation of 60 inches or over. This rain falls chiefly in the summer months, hence the greatest growth of cane takes place during the summer. The advent of the dry winter months sets a period to the rapid growth of the cane, a factor which is of great service to the miller. The drier months cause the cane to "ripen"; the moisture in the plant is greatly reduced, and thus the sap has a higher percentage of sugar in the juice. The dry weather is also favorable for harvesting operations, as it allows of the trash being removed by burning—an easy way for the planter, but not the best.

The dry weather generally commences in April, and may extend until August or September. These are the months when the crushing is done, though latterly, due to labor trouble, etc., the mills have been running almost the whole year round, leaving off only for a space of time sufficient to overhaul the plant. Natal's precipitation is not sufficient to mature a crop of cane in twelve months, nor is it tropical enough to do this. Zululand is better in this respect. There, cane will be ready for cutting eighteen months after planting.

Soil Requirements.

A crop which is capable of growing to the amount of 60 tons per acre every two years demands soil which is very well adapted for plant growth. The factors required for growth are three in chief: (1) Moisture, (2) plant food, (3) heat. To these should be added a favorable mechanical condition of the soil. The soils in the cane are two chief types, with several variations in different directions from the types. The two types may be contrasted as follows:

(1) *Red Hillside Soil.* (a) The hill soils are free workers; (b) Never become water-logged; (c) Are very easily penetrated by cane roots; (d) Are not so rich in plant food; (e) Dry out sooner in dry weather, but can be worked even when dry; (f) Are the earlier soils, from which cane should be harvested the first; (g) Have the better mechanical conditions; (h) Are not sour.

(2) *Black Vlei Soil.* (a) The vlei soils are more difficult to work; (b) Tend to become water-logged in summer; (c) Cane roots penetrate less deeply; (d) Are richer in plant food; (e) Dry out more slowly, but when dried cannot be cultivated; (f) Cane may stand longer on these soils without harm resulting;

* E. R. Gessner, in The South African Sugar Journal, Sept., 1919.

(g) Have the poorer mechanical condition; (h) Are usually sour.

From the above, it is evident that considerable differences exist, and both types of soil will most likely occur on any holding. In addition to these two types, mention should be made of a third type found along river banks and flats, soils liable to be flooded at times of heavy rain, but excellent producers when climatic conditions are favorable.

When a planter is starting operations upon new land, he will probably start with the hillside type, as being the more readily brought into condition for planting. Far more experience is required to handle heavy vlei soil than is necessary with hillside lands.

Hillside or vlei land may both be covered with indigenous trees or bush, or be mostly in grass. In the latter case the operations are the easier, and will be considered first.

Plowing and Ridging.

(1) If the grass is not too long and rank to be plowed under, it should be so treated. If plowing would leave considerable quantities of grass uncovered, then the material should be burnt off in order to enable a thorough preparation of the soil before planting.

The best plows for breaking up new lands of this description are mould-board plows with disc coulters, oblique shares and long shallow convex mould-boards. Such a plow will roll over the furrow slice completely, but will not pulverize it to any extent.

Land which is full of grass roots of this description should be allowed to lie some time after plowing, if possible, in order that decay of roots may crumble the soil and facilitate further operations. In some cases, where the planter must push ahead with the soil preparation work as fast as possible, time cannot be spared for this mellowing action to take place.

After plowing, the soil should be harrowed across the furrows with a cut-away disc or ordinary disc harrow, giving two or three harrowings in the same place if necessary. A second plowing across the furrows of the first plowing should pulverize the soil fairly well, so that when harrowed with zig-zag harrows it is in fairly good tilth and ready to be ridged and planted. The furrows or drills in which the cane is planted should be about 5 feet apart and 6 inches deep. If the land has been brought into good tilth these furrows can be made with a double mould-board plow. If the tilth is poor, completion of furrows made with the double mould-board plow must be done with hoes, adding considerably to the expense of establishing the crop. As the initial preparation of the soil is required for at least eight to ten years, it is imperative that it be thorough and not shirked, or poor crops will result for the whole of that time.

(2) Where there are trees to be cut down, the initial expense is greater, and these will retard the plowing, harrowing, etc., of the land. Under such conditions, when the trimmings from these trees have been burnt, the soil is ridged with hoes as well as possible, leaving stumps to decay in the ground. The after-working of the cane on land which has grown bush is also more expensive, as it is not possible to use mule or ox labor in the cultivations. All cultivations require to be done by hand.

(3) The third type of land is that which is carrying heavy bush, wild banana, etc. This land grows good crops of cane when cleared, but the expenses incurred in clearing are very heavy, and such land will be left until the last. This is land which is on the margin of cultivation. It is estimated that the cost of clearing such soil, grubbing out wild banana and other stumps to bring the land into condition for plowing will cost £10 per acre. Further plowings, harrowings, drilling, seed cane, planting, weeding and earthing up will cost £4 10s. per acre, making a total cost to establish plant cane under these conditions £14 10s. per acre. This is a very heavy initial expense, and requires large returns for a number of years to compensate the planter for the heavy cost involved.

The heaviest item in this class of land is the clearing. This may be somewhat reduced by the use of "Forest Devils," implements for stump extraction. Six strong natives working one of these will deal with anything up to half an acre per day. With the large stumps, the tap root should be eased by means of choppers, and then the stump can be extracted, as the side roots do not give much trouble. This implement is also of use on cane fields where stumps were left in and planting done by means of making furrows with hoes. After the plant crop is harvested, the old stumps can readily be removed. Such areas can then be cultivated by horses, mules or oxen, with cultivators or pony plows for inter-row work. Stump extraction with dynamite has been tried on the sandy soils of the coast but without success.

Where much bush has been removed, the plowings are frequently dispensed with, ridging being done with hoes. In making the furrows or drills on such lands, the earth should all be placed at one side of the drill, and when the cane is being planted it should be covered with soil taken from the other side not worked. By carrying out this method, weed growth is checked considerably, and this enables the young cane shoots to get well ahead of the weed growth. The young shoots are more easily seen, and are not so likely to be damaged during cleaning operations.

The cost of establishing cane on ordinary grass lands with a small amount of bush is about as follows: Plowing, 10s. per acre; harrowing, 1s. per acre; grubbing out roots, 15s. per acre (burning grass undergrowth, etc.); drilling out, 15s. per acre; cost of plant cane, £1 per acre; planting and covering, 5s. per acre; first weeding, 10s. per acre; second weeding, 7s. 6d. per acre; third weeding and earthing up, 12s. 6d. per acre—making a total cost of £4 16s. per acre. Where more than one plowing and harrowing has to be given, the cost of establishing the cane will be higher.

Planting.

In planting, the furrows or drills are usually spaced about 5 feet apart, are 9 inches wide and 6 inches deep. A double line of cane is laid along the bottom of the furrow and covered with about 2 inches of soil.

Experiments have been carried out at the Government Experiment Station at Winklespruit with plant cane in order to find out the best age, etc., of plant cane for its purpose. The experiments have been duplicated at different times,

and the results secured have shown that canes twelve months old are the best for planting.

The portion of the cane which is planted is the stem, and, as with other stems, more vigor is shown in the younger parts than in the harder parts. In picking cane for planting, care should be exercised, and only the strongest, healthiest and vigorous stools used. There is too little attention paid at the present time to the selection of canes for planting purposes. The age of the crop from which the plant cane is taken should be from twelve to fifteen months, and the crop should be either the first or second crop after planting, i. e., plant cane or first ratoon. The cane should be trashed before planting, so that imperfections, poor growth, disease and insect trouble may be observed and eliminated. Cane of the age indicated gives a good stand of young cane and an earlier growth, with the result that less labor is required for weeding and keeping the crop clean, due to the greater vigor of the crop.

It has also been noticed that a better growth is secured from the middle and tip portions of the canes than from the butts, and this in both the Uba, the standard variety, and the Agaul, a recent introduction from India.

Cultivation.

Should the plowing and planting have been carried out in a thorough manner, the crop will be in a position to start well, providing beneficial rains are experienced. The cultivation given in the preparation of the land for the crop is not sufficient, however, to ensure a good crop without further attention. In tropical areas, weed growth is so luxuriant and so rapid that much work has to be bestowed upon the crop to keep it clean. In the drills where the cane is planted there should not be much weed growth, but between the rows there will be plenty of weeds. In the hoeings and cultivations which are given, the soil from between the rows is gradually worked up to the cane as it grows. The first weeding is generally done by hand, the second one by cultivators, and with the third one the canes are banked up by means of a small single-furrow pony plow, plowing the furrow towards the row of cane. For cultivation work, mules are the most suitable. Oxen are somewhat destructive to young cane, and are slower than mules. Mules, again, are hardier than horses, can be better immunized against horse sickness, and are less costly to keep, thriving on poorer fare and under worse conditions than horses will do.

One point worthy of note is that, where soils are somewhat shallow and where deep-rooting varieties are used, a single-line scarifier may be run along the bottom of the furrow before planting takes place. This tends to increase the soil space and its water-holding capacity, and to favor the deep penetration of the roots.

Planting is generally done from September until the end of the year, but the operation is dependent to a considerable extent upon the rainfall.

Varieties of Cane.

The variety of cane which is most largely grown in Natal and Zululand is the "Uba." This cane has proved itself to be the best adapted to local conditions for a very considerable time. The varieties which were grown in Natal in the early

days of the sugar industry have been superseded, and many introductions since the Uba have been discarded. It is evident that the Uba variety will run the risk of "growing itself out" unless greater care is bestowed upon the selection of the canes for planting. With care bestowed upon the selection of the cane for planting for some time, the average of the last season's crop at the Winklespruit Station was 35 tons per acre, no fertilizer being applied.

The Uba cane is a somewhat thin cane, yellowish to yellow-green in color, and with internodes which attain a length of 6 inches or more in well-grown canes. Where the conditions for growth have been unfavorable, the internode length is much shortened, as they also are when the cane is nearing maturity. The Uba is a hardy cane, and, from the miller's viewpoint, is possessed of several undesirable characters, in that it is high in fiber content and requires more power to crush and handle than the softer varieties. It is possessed of splendid ratooning powers, and this is a factor which has chiefly to do with the large area under this variety. Where conditions are favorable, four or more ratoon crops may be secured from the one planting, so that the crop occupies the soil for ten years or more before replanting is necessary. It is thus evident that a thorough initial preparation of the soil is much to be desired. The dead leaves of this variety remain adherent to the stalk, or, in other words, the cane does not trash itself. This necessitates trashing before harvesting, or, as is often done, though against scientific principles, burning.

It is a deep-rooting cane, readily adaptable to varying conditions of soil, for it is to be seen growing upon the blackest of alluvial loams to the reddest of shallow and dry hillside soils. It is hardy and resistant to both fungal and insect attack. In Natal and Zululand, so far as is known to the writer, fertile seed has never been produced by this variety. The cane arrows or flowers fairly frequently in some seasons, and more so on the red sandy loams than on the richer soils. This would seem to be in accord with the general law that, where the conditions are most favorable, vegetative propagation will keep the plant going, but that as soon as unfavorable conditions appear an endeavor is made to produce seed. It is only from seedlings that the combined characters of Uba, along with those of other canes, can be obtained, and the crossing of different kinds must, therefore, be carried out in other countries.

The Agaul cane, as already noted, is a fairly recent introduction from India, and greatly resembles the Uba cane in every respect. It is, however, a more vigorous cane, surpassing the Uba in rapidity and luxuriance.

Soft Canes.

These canes are much thicker than the Uba, and the individual canes several times heavier than the individual Uba canes. They are not adapted for growth upon hill soils, but find conditions best suited for their growth in the richer, heavier, alluvial and vlei lands. Generally speaking, they compare badly with the Uba. They are strictly limited to certain areas; they are shallow rooters, poor ratooners, more liable to be attacked by fungal diseases and insect pests, and suffer more from winds. It is no uncommon thing to see soft canes so blown and twisted about that one is unable to distinguish which way the lines run. They likewise suffer very much during droughty spells. They yield heavier returns

for the first season than the Uba, but after one season's growth they ratoon badly, and subsequent growths cannot compare with the ratoon crops of Uba. They are thus seldom grown in this country.

Varieties of soft canes which have been tried at the Winklespruit Experiment Station are: Six varieties from Demerara, ten varieties from India, four varieties from Antigua, two varieties from Queensland, three varieties from Egypt; other varieties: Horne, Honolulu, Rose Bamboo, Green Natal and Louisier have also been tried. Latterly, several varieties of cane introduced by the Natal Sugar Association from the Argentine have been planted at Winklespruit, and are being tested alongside the standard variety Uba. At the time of writing, these canes are growing quite nicely, and appear promising. In other parts of the world the soft canes are largely grown, but there planting is usual every year. Powers of ratooning are not of great value where annual planting is the practice.

Harvesting.

The crop from Uba plant cane generally takes about 22 months from the date of planting to mature for crushing purposes. Ratoon crops are ready for crushing at about 20 months after the previous crop has been removed Both of these periods are liable to alteration, due to the great influence exercised by the variable weather conditions. The soft canes mature in about 12 months, but the returns from a plant cane crop are only about the same as from the Uba. The soft varieties demand greater heat and moisture and richer lands than the Uba, and, therefore, cannot oust it from the position which it occupies in this country.

The actual cutting of the cane is done by hand, after the trash has been removed either by hand or by burning. The former method is advocated as yielding back to the soil the organic matter which it so much needs.

Native and Indian laborers are employed for the cutting, which is done with large cane knives. It is important to see that the cane is cut low, almost into the ground and as near the stool as possible. The root end of the cane is richer in sugar, and if stumps are left, these tend to decay, and the disease may spread to the living stems. The vigor of the ratoons also appears greater when close cutting is practised. Four good workers will cut and load six tons of cane in a day. Cane should be forwarded as soon as possible to the mill after cutting, lest undesirable fermentations take place in it. After cutting, the cane is forwarded to the mill either by wagons or by small trucks on tram lines.

The latter are the better and easier way, though the initial outlay is larger. The loading of the cane into wagons and off-loading and loading into railway trucks is a laborious and costly operation. When the density of the juice is at its highest, it requires about eight tons of Uba cane to yield one ton of sugar, but frequently the amount required is considerably higher than this, especially in wet seasons.

Full reports dealing with the effect of artificial manures upon sugar cane are to be found in Vol. III, "Cedara Memoirs," obtainable from the School of Agriculture, Cedara, and also in a bulletin on "The Sugar Industry," by Mr. C. Williams, B. Sc., Chemist to the School of Agriculture, Cedara.

Future Development.

The production of sugar in South Africa has now reached that stage when it will be necessary for it to enter into competition with sugars grown in other parts of the world, and, this being the case, it behooves the producer to examine the method of production in order to ascertain if the system in vogue is the cheapest and best.

The price of sugar on the world's market will not fluctuate very much, and though there is a tendency for civilized nations to consume more sugar, this increase probably hardly keeps pace with the increased areas put under sugar cane. The present tendency is for wages to rise, so that any method of cheapening production is likely to find favor in the eyes of the producer.

On large tracts of land suited for steam plowing, etc., this form of power will be utilized. On smaller areas motor power may yet find its place. The beginner, however, will probably be dependent upon oxen or mules. Lands must be so laid out that practically all the cultivation can be done by oxen or mule labor. Hand-weeding must be dispensed with. On land where there is no trash to interfere with cultivators, these should be used as far as possible.

Selection of higher yielding stools should also be practised, and high-yielding stools should be tested out individually, so that the best producing strain may be secured. In these ways, by lowered cost of production and increased return, the planter should be able to earn a good living from sugar production.

[J. A. V.]

Flies.

By Donald S. Bowman, *Industrial Service Bureau, H. S. P. A.*

The common flies found in our plantation villages are responsible for the spread and development of typhoid fever in the majority of cases. That the human typhoid carrier has much to do with the spread of the disease from plantation to plantation has been demonstrated many times by sanitarians. The privy vault is the favorite breeding place for the fly; there he harbors until the vault is used by a typhoid carrier. His flight in general is from the privy to the food supply, which he contaminates.

Years ago on one sugar estate on Hawaii typhoid was prevalent in a village near the sea coast. The open privy was in use, and flies multiplied rapidly. Acting upon the advice of a sanitarian who determined that flies were responsible for the spread of the disease, a system of water-flushed toilets were installed, and in a short time typhoid was eliminated and there has been no recurrence of the epidemic. Other instances of a like nature might be cited as having occurred throughout the Islands and in many communities on the mainland. For

our health protection the fly must be fought; and we know of no better health insurance than the intelligent expenditure of money on sanitary measures that will rid the villages of fly-breeding nuisances.

"The Transmission of Disease by Flies," by Ernest A. Sweet, of the U. S. Public Health Service, is here reprinted.

The Transmission of Disease by Flies.*

By Ernest A. Sweet.†

(*Contributed by the Industrial Service Bureau, H. S. P. A.*)

Insects play a definite rôle in the transmission of disease, a fact which has been conclusively demonstrated over and over again. Many of the most serious ills of man are conveyed from person to person through the medium of mosquitoes, flies, lice, ticks, and other forms of vermin. How the transmission of disease is effected, the particular insects acting as carriers, and the means of combating such pests have all become matters with which the public is concerned.

Of the natural enemies of man, the fly unquestionably takes precedence over all others. Possibly there may be some tendency to accord to the mosquito this unique position, but if a careful summary be made of the activities of both flies and mosquitoes, the former, it is believed, will necessarily be rated as the more harmful and dangerous. Only recently has it been possible to convict this insect of the many crimes and misdemeanors of which it is guilty. We now know that flies, instead of being harmless insects, of moment only when they invade our food supplies, are in reality highly dangerous, and that a single fly may be responsible for the development of typhoid fever or other illness of a serious nature.

Kinds of Flies.

There are many kinds of flies, not all of which have the same structure, habits, or methods of reproduction. In a general way, however, the families resemble one another, and while the following description applies principally to house flies, with slight modifications it is applicable to other varieties as well.

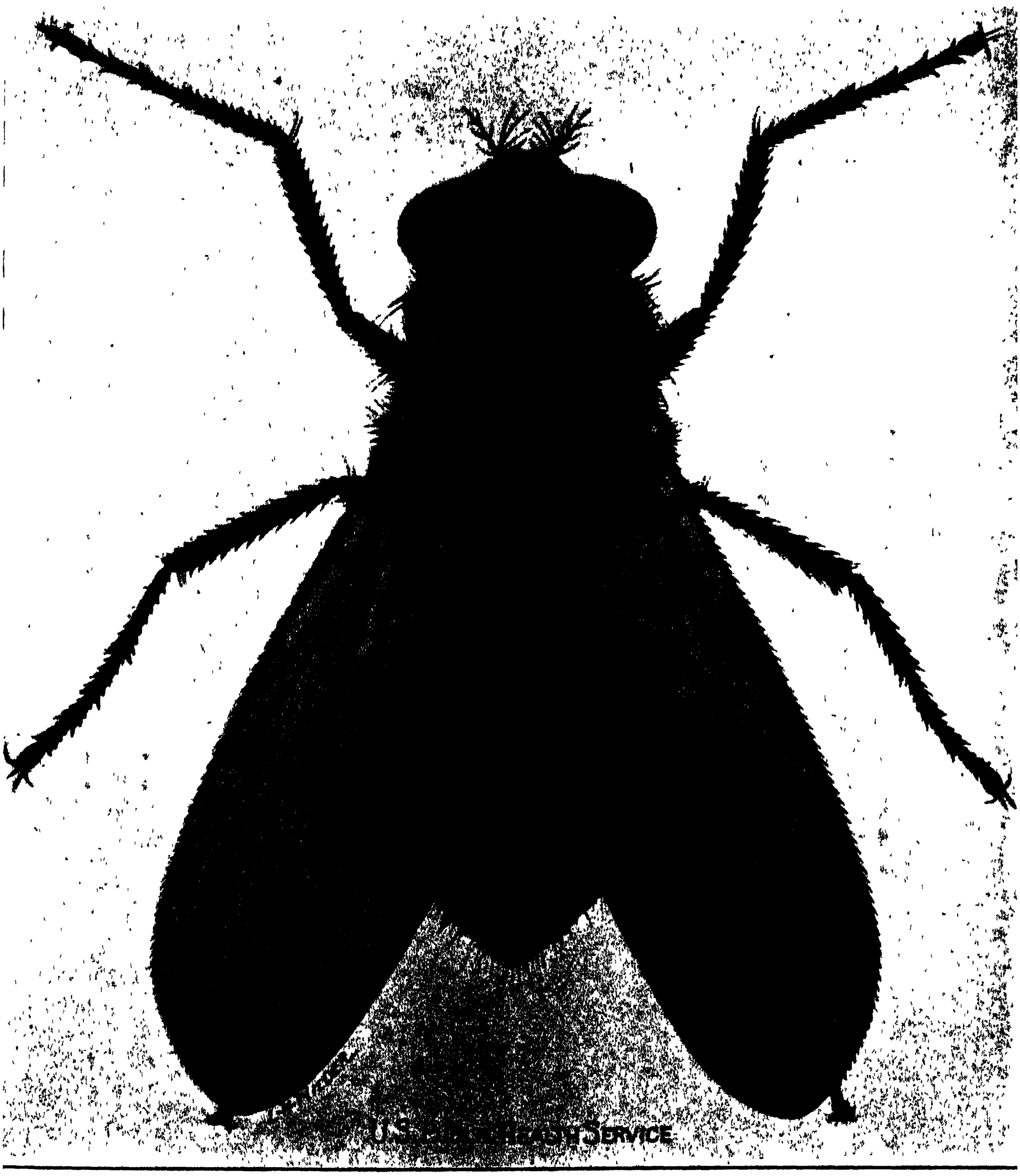
The most common and widely distributed of all flies is the house fly. This insect is ordinarily present in all parts of the world and lives in practically any climate adapted to man. Nine-tenths of the flies found within or near dwellings belong to this group, although a number of other species so closely resemble house flies in appearance that differentiation may be impossible by other than experts. The favorite haunt of the house fly is the dwelling of man, and it is seldom found away from human habitations.

The bluebottle, or blow fly, is a second ~~familiar~~ species, owing to the characteristic and disturbing noise made in its flight. It has a strong liking for the

* U. S. Public Health Service, Supplement No. 29 to the Public Health Report.
† Passed Assistant Surgeon, United States Public Health Service.

exposed surfaces of fresh meat and fruits, the former seemingly having a powerful attraction for the insect, but it is not averse to entering houses.

Bearing a strong resemblance to the bluebottle fly is the greenbottle fly, which is slightly smaller and metallic green in color. It is commonly found near putrefying flesh, such as dead animals, excreta, and similar filth. A member of this family often breeds in the excrement on the backs of sheep, the larvae or maggots developing and feeding thereon, resulting in a serious pest to flockowners. When the larvae mature in either filth or flesh they are especially voracious and consume a large part of the substance on which they are developing. The fact that insects of this family alternate between human excreta and food products



The House Fly.

renders them especially dangerous, although their number is usually limited and they are seldom satisfied to remain within doors.

One of the most important species is the stable fly, or, as it is sometimes called, the "biting stable fly." It is less often found in filth than the other varieties, but owing to the fact that it is a blood-sucking fly, opportunity for the direct inoculation of persons and animals with the organisms of disease is presented. It is this insect which has been incriminated in the spread of anthrax. The stable fly is about the size of the common house fly and resembles it in appearance, being gray in color and somewhat more stoutly built. Its proboscis, however, is of an entirely different character, as campers and others can testify, being arranged for penetrating and sucking. It frequently torments horses and cattle and may even cause detriment to stock through its activities. The insect is widely distributed. Closely allied to the stable fly is an African species known as the tsetse-fly, which is responsible for the spread of sleeping sickness, a fatal infection found in certain regions of the African Continent.

The "lesser house fly" is the name given to a species which, next to the house fly, is the most common indoor resident. Probably everyone has observed the useless and apparently aimless, jerky flight of this insect beneath some suspended article, such as a chandelier. This fly is an early visitor, usually being found before the common house fly is present in large numbers. Its breeding habits are the same as those of the house fly, but as it feeds less diligently and seldom alights, it is somewhat less objectionable. It strongly resembles the house fly, but is slightly smaller and more slender, being, perhaps, better adapted to flight. The larval form of this fly is easily distinguished from that of the common house fly, as it is covered with spines.

In addition to the species enumerated, many other bloodsucking and non-bloodsucking varieties are of interest. The cheese fly deposits its eggs in cheese or fatty material, producing the so-called cheese skippers. The dung and the yellow dung flies and the latrine fly are so named because they develop in the excrement of animals or man. The fruit fly, a much smaller species than any of those mentioned, hovers about fruit juices, cider barrels, and like situations, being often found in the dregs of wine. None of these species, however, is as important as the common house fly.

Structure.

The parts of the fly are the head, thorax, and abdomen. The head is connected with the thorax by a narrow neck which permits of rather wide movement. The greater part of the head is occupied by the eyes. some several thousand in number, described as compound. Between the compound eyes and near the top of the head is a triangular arrangement of three simple eyes. The upper two are much farther apart in the female than in the male, thus serving to easily differentiate the sexes. In spite of the arrangement of the eyes and the great mobility of the head, it is not believed that the vision of flies is especially acute, although the range of vision is wide. The sense of smell, however, is highly developed.

The proboscis protruding from the under and back part of the head is the most interesting part of the fly. When the insect is at rest, the proboscis is

folded against the head, but upon alighting it is protruded through the mechanical action of certain air sacs. Capping the end of the proboscis are two oval projections or lobes forming an opening leading into the mouth. The oral lobes in the house fly entirely prevent penetration of the skin by the proboscis, therefore this particular species is in no sense a biting fly. Biting invariably constitutes positive proof that the insect is not a house fly, however much it may resemble that species. On the under and inner side of the oral lobes are grooved channels which lead into the mouth. When these channel-like surfaces are placed in contact with liquids, suction is performed by the pharynx and the substance is drawn into the œsophagus, to be continued through the narrow neck into the thorax. If the food is solid it must first be dissolved through the action of saliva secreted by the salivary glands or reduced to very minute particles.

The greater part of the thorax is occupied by the muscles used in flying, these being placed above the stomach. Connecting with the œsophagus after it passes into the chest is a small duct leading to a dilatation within the abdomen known as the crop. From this receptacle feed is frequently regurgitated, appearing at the mouth parts in the form of small globules, to be again devoured at the insect's leisure. It is this habit of regurgitation, or vomiting, which renders flies extremely objectionable from a sanitary standpoint, particularly as the stomach contents are obtained in most instances from filth and garbage.

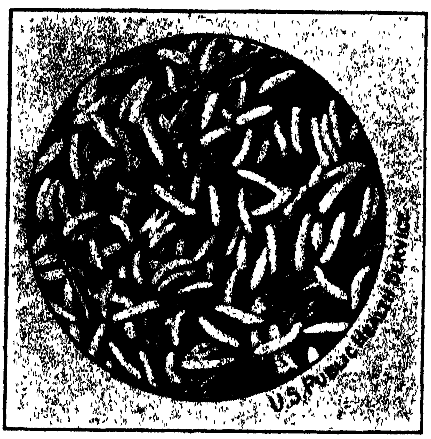
Several segments make up the abdomen or after portion of the body, the number varying with the sex and species. The last four segments in the female form the ovipositor. Owing to its telescopic character, this organ may be partially withdrawn within the abdomen or extended when in the act of depositing the eggs. In this manner eggs are laid in cracks and crevices or deposited beneath the surface of filth, thus affording excellent harborage for the larvae. During the breeding season, which continues throughout the summer months, the abdominal cavity of the female is densely packed with eggs.

The wings are attached to the thorax and are characterized by dark lines or veins extending through the wing membrane, the markings varying with the different species. There are three pairs of legs, all rather thickly covered with hair. Both the legs and wings are admirably adapted to the mechanical transference of substances with which they come in contact. It is this interchange of material, derived in many instances from polluted and filthy sources, which constantly exposes man to the danger of disease.

Reproduction.

Flies are extremely prolific. The stages in the life cycle occupy at the most but a few days, and sexual maturity is reached within three or four days from the date of birth. As the eggs deposited by the female usually number a hundred or more, an enormous increase in the fly population is possible within a short period of time. Like many other insects, flies pass through several developmental stages, the immature forms differing radically from the adult. There are four stages in the developmental cycle, namely, the egg, then the larva or maggot period, next the pupa, chrysalis or resting stage, and finally the adult fly. A thorough understanding of each of these stages is essential for a proper appreciation of the rôle flies play in disease transmission.

Nearly all flies breed in organic filth. A favorite medium is horse manure, but decaying vegetables, fermenting kitchen refuse, human excreta, and putrefying animal matter offer sites which are nearly as well adapted to the conditions necessary for propagation. The barn manure pile may be the place of origin of thousands of flies, the unprotected and unscreened privy serves as an excellent nidus for their growth, while fermenting foodstuffs and other waste food products scattered about the yard may also assist in their propagation. But three conditions are necessary for fly propagation in filth of this character, namely, proper temperature, moisture, and food supply. The warm manure pile and the decaying and fermenting garbage heap admirably fulfill these conditions. The swarm of flies invariably seen about places of this character during the summer season is an indication that not only feeding but actual propagation is in process.



Mass of Larvae in stable manure.

The breeding season varies with the climate, usually beginning during May in the North, but more often in early April or March in the South; propagation continues until late September. The fly population is usually greatest during August and September, after which it very rapidly diminishes.

The eggs of the common house fly are smooth, white, glistening bodies about a twentieth of an inch in length, oval in shape and slightly broader at one extremity than the other. They are usually found in irregularly massed batches, each female depositing several such aggregations during her lifetime. The long ovipositor enables the female to deposit the eggs in crevices or beneath the surface of filth where the desiccating action of the atmosphere is less pronounced. Ordinarily a period of but 12 hours is required from the time the eggs are deposited until they are transformed into larvae, although if the temperature is not favorable, two, three, or more days may be necessary. Hatching merely consists of the splitting of one extremity of the egg sac and the emerging of the larva.

The larvae, or maggots as they are commonly known, represent the second stage in the development of the fly. They are about twice the size of the eggs but of much the same color and shape, the body being somewhat indistinctly segmented. There are no legs; nevertheless, by aid of the mouth parts and rudimentary enlargements on the under surface of the body the larvae are actively motile and may travel a considerable distance. During the course of their growth they pass through two moults, constantly feeding upon the substance in which they are contained and reaching maturity in from 3 to 6 days. The larvae exhibit a tendency to congregate in a zone just beneath the surface of the mass upon which they are developing, seldom being found directly upon the surface. After arriving at maturity they migrate or leave the substance where they commenced their growth, burrowing into the soil or even traveling a distance of

several feet over the ground. This migration must always be considered and guarded against when fly-eradicative measures are instituted.

When the fly reaches the third or chrysalis stage of its development it is known as the pupa. This period is characterized by a contraction of the body, a change to a darker color, and a disintegration of the larval parts, with a corresponding growth of the wings and other structures of the future fly. The pupal stage ordinarily continues for about three days, when the adult and fully grown fly emerges from the sac. After exposure for a short time the integument hardens, the wings dry, and the insect is ready for flight.

Under average conditions the entire cycle of development from egg to adult fly occupies a period of only from 8 to 10 days, but the time may be prolonged under unsuitable conditions of temperature or food supply to 20 days or more. When the eggs are deposited upon nonfermenting vegetable matter, the period may also be somewhat lengthened, but the instinct of the female invariably leads her to place her eggs in the most favorable locality. The important consideration is, however, the ordinary developmental period, from 8 to 10 days. Manure, filth, or garbage which has been exposed for a longer period than one week is almost sure to breed flies. The removal of such filth and manure as often as twice a week, or its proper protection, will largely prevent the breeding of these insects. The relation between the quantity of such material present and the number of flies is always direct and definite and its removal is invariably followed by a decrease in the fly population.

Habits.

In its habits the fly is probably the most objectionable insect with which man comes in contact. It not only breeds in filth, but it continues to frequent objectionable material throughout the days of its existence, leaving it only to invade the residence of man, contaminate his food, and oftentimes to spread disease.

House Fly regurgitating liquid material.

The house fly is a persistent feeder, but the feeding process itself is somewhat slow. Flies are very industrious in their search for food, even when it is right at hand, crawling over the surface thereof and evidently searching with the proboscis for more dainty morsels. On their excursions of this character

they may carry with them, particularly on the hairy parts of the legs, the organisms of infectious disease, the eggs of various parasites, and organic filth. Should they next visit our tables, this dangerous material is distributed over our food. When food so contaminated is taken into the stomach, man is directly infected and may develop any one of a number of diseases.

Another manner in which flies disseminate infection is through the regurgitation or vomiting of food. It is unpleasant to consider that insects which have but recently frequented garbage heaps, cuspidors, and manure piles may be guests at our tables, but it is all the more disgusting to consider that the very material of which they have partaken should be subsequently distributed over our own food and then received into our system. Similarly, the numerous brown excreta spots or fly specks on walls and ceilings which are the bane of every housewife prove by their very location that they should be far less the objects of hatred than those which are deposited elsewhere. The number of such vomited and fecal spots deposited by well-fed house flies may be enormous, frequently rising to a hundred or more a day.

The range of flight of house flies is ordinarily not great. They probably seldom travel more than half a mile from their breeding place unless carried by winds, and usually remain within 200 or 300 yards of their point of origin. Therefore, if flies are found in a particular neighborhood it is fair proof that they developed in the immediate vicinity. The range of flight may be ascertained by anyone who is interested in such experiments by coloring insects with aniline dyes and, following their release, recapturing them either by traps or fly paper at various distances.

Flies are attracted to houses either by the odor or presence of food. Warmth also proves seductive. In cold weather they seek shelter to hibernate, crawling into unexposed places and living for several weeks in a semidormant condition. Following the onset of warmer weather they revive and become the forbears of a numerous progeny, thus continuing the race from season to season. For this reason exterminative measures are of greatest value if begun early. It is also probable that continuance through the winter season is due to the prolongation of the egg and larval stages by the low temperature. In spite of a considerable resistance to cold which flies manifest they are at the same time quite susceptible to its influence, preferring quietude to activity when so affected. Sunlight and brightness are usually attractive, a fact familiar to every housewife.

Carriers of Disease.

Flies may transmit disease in either of two ways. The first method is by mechanical transference, whereby the insect becomes contaminated with the parasites or microorganisms of disease as a consequence of frequenting filth and places where these agents abound, thus carrying pathogenic organisms directly to food or drink partaken of by man. This is by far the most common method of conveyance. All forms of flies may act as disease carriers in this manner, but the house fly is the principal offending species owing to its prevalence and great tendency to frequent filth. As previously stated, the body of the fly, with its stiff, hairy parts, is well adapted to transference of contagion in this manner.

Experiments have been conducted to show the length of time flies may carry

the organisms of infection, but this naturally varies. If conditions are favorable, there is little doubt that bacteria may be transferred in this manner after several days. If the organisms are taken into the intestinal tract of the fly, this period may be lengthened, the feces serving as the agent of transmission and prolonging the infective stage. When it is realized that milk, which is one of the best media for the growth of bacteria, may be contaminated by flies merely through the act of feeding and that "clean flies" may even derive infection from those which have but recently visited outhouses and stables, the dangers of food contamination may be conceived.

The second method of disease transmission is by inoculation, that is the actual injection into the system by the insect of pathogenic organisms or parasites. Fortunately, disease can not be transmitted in this manner by the nonbiting flies, else our safety would be far less than at present, the bloodsucking varieties being only those which are of danger in this respect. In our country these varieties are relatively infrequent. The mode of transmission is similar to that in which malaria is conveyed by the mosquito, typhus fever by the louse, and plague by the flea. The parasites or organisms derived from the blood of the infected person are received into the stomach of the fly, where they may undergo developmental changes requiring a specified period, and are subsequently inoculated into a second individual.

Of the diseases which may be transmitted by flies, the following are worthy of consideration: Typhoid fever, diarrhea and enteritis, cholera, dysentery, paratyphoid fever, intestinal parasitic infections, sleeping sickness, surra, nagana, with a number of others where there is a dictinct possibility of transference.

Typhoid fever is the most common and important infection of man conveyed by flies. It is an acute, infectious disease of bacterial origin, contracted only by taking into the system the bacteria containing discharges of one actually ill of the infection or of some person who serves as a carrier thereof. It may be contracted through sewage-polluted drinking water, infected shellfish, or in other manner, the only requisite being the presence of the typhoid bacilli in the food or drink of man. It is essentially a disease of filth, but unless means are established for the transference of such filth to the mouths of persons the infection never develops. Flies frequently serve as the means of this transference, and are therefore in part responsible for the dissemination of the disease. In the United States alone during 1914 over 14,000 persons died from typhoid fever and ten times that number suffered from the infection, the rate being several times higher than that of many civilized countries.

Attention was called to the agency of flies in the transmission of typhoid fever during the Spanish-American War, when hundreds of our soldiers died from this altogether preventable infection. It was clearly established that the high incidence of the disease was in part due to the presence of myriads of flies which visited the unscreened and unprotected latrines, later to be accorded free access to the kitchens and dining halls of the troops, where every opportunity was available for the contamination of food. In certain instances the very chemicals used in covering discharges were found upon the bodies of the insects and occasionally upon the food itself, indicating that fecal matter was present and that infection in this manner was possible. The investigations of that time

have since been confirmed, and it is now a well-recognized fact that whenever flies have access to the discharges of man and at the same time to his food supply, disease will necessarily occur.

The conditions which prevailed during the Spanish-American War exist in thousands of American communities today. We look with horror upon the frightful and unnecessary sacrifice of lives which then ensued, yet within our very vision identical conditions prevail and we remain quite undisturbed. The unscreened and unprotected privy constitutes a grave and serious menace to the health of any community. Sooner or later it is bound to become the depository of typhoid excretions, and at that moment it becomes a hazard to every resident in the vicinity, for that very environment has created an insect host capable of disseminating the scourge to every point of the compass. It should be understood that typhoid-fever bacilli never originate in flies themselves, but are always derived from infected human dejecta. Not only are the bacilli contained in the feces of man, but in other excretions as well. Persons actually ill of typhoid excrete enormous quantities of such organisms, but these cases may actually be of less danger than others, inasmuch as in the majority of instances proper disinfection and disposal of such material is secured. Many persons, however, continue to excrete these dangerous organisms long after they are well, in some instances for years, and thus are a constant source of danger to the public. So common is this condition that at least 2 per cent of those who have recovered from the disease can be rated as typhoid-bacillus carriers. Again, walking or ambulant cases of typhoid are frequent, and in certain instances the condition goes unrecognized or is mistaken for something else, so that necessarily there is, and will continue to be, serious danger through the medium of flies from these apparently harmless persons. In unsewered districts this hazard is proportionately greater, but even in sections properly provided for in this respect the menace is never negligible if flies exist.

Flies which have access to outhouses and to tables may contaminate any variety of food. Milk is frequently subject to infection, and numerous epidemics of typhoid with resulting deaths have been traced directly to dairies unprovided with proper facilities for the disposal of excreta. Given a typhoid carrier and the presence of flies, together with an unprotected privy vault, and the stage is completely set for the development of the drama of disease. Food purchased in fly-ridden markets may likewise be a source of contamination, and if eaten uncooked may lead directly to illness. Cooked food of whatever nature may be contaminated subsequent to the cooking, constituting a serious menace to health. Irrespective, then, of the precautions we exercise as individuals, we are all more or less exposed to the infection of typhoid fever through common sources. Further, as a result of the laxity of others, even when we ourselves may have exercised every precaution necessary to prevent the development of flies, our lives are frequently endangered.

A second infection, and one analogous to typhoid, frequently conveyed by flies, is summer diarrhea. This is more particularly a disease of children, but adults are also susceptible. Annually in the United States 70,000 infants under 2 years of age die from diarrhea and enteritis, the infectious nature of which has now been definitely determined. Bacteria of various varieties are known

to be responsible for the disease. The sources of infection are much the same as in typhoid, the causative organisms reaching the alimentary tract as a result of uncleanliness, infected food, and very possibly by contamination of hands or food through the activities of flies. The evidence against the fly as a conveyor of the infection is largely circumstantial, yet so conclusive is it that no one would fail to place the responsibility upon this insect.

First, the disease exists in the summer season, when flies are known to be prevalent. Its incidence varies directly with the incidence of flies, the summer diarrhea curve and the fly curve practically coinciding. This in itself is suggestive. Further, it has been demonstrated that flies are important distributors of bacteria, that they frequent localities where infective organisms are deposited, and that following eradicative measures directed toward these insects there is almost invariably a decrease in the prevalence of intestinal complaints of this character. It would therefore seem that, in the light of our present knowledge, we are warranted in the conclusion that flies play a definite rôle in the dissemination of the disease. If we wish, then, to save the lives of the babies, the very first step in the process is the eradication of flies.

Cholera and dysentery, which are primarily intestinal affections conveyed in the same manner as typhoid, are unquestionably at times disseminated by flies. Each is a bacterial disease due to a specific organism, the development of which follows the ingestion of water or food contaminated in some way from the discharges of a person ill with the disease or who excretes the bacilli thereof. It is reasonable to suppose that in a certain percentage of cases flies may act as the distributing agent, and this has been well established with the first-mentioned infection. Fortunately, cholera is a rare affliction in this country, originating only from imported cases, but epidemics of dysentery are not uncommon, being especially prevalent in institutions, camps, and districts where insanitary conditions prevail.

In addition to the intestinal diseases cited, certain other affections, more or less closely related thereto, may at times develop as a result of the activities of flies. Paratyphoid, a first cousin of typhoid fever, and food poisoning are to be considered in this category. More important still, however, are the numerous parasitic worms, such as the various species of tapeworm, hookworms, and even those of rarer forms, all of which are continued through the media of ova or eggs contained in the feces of infected persons. Many species of flies are attracted by the ova of such worms and readily devour them, with the possibility of passing through the fly undigested, with later transference to articles of food and thence to the mouths of persons, thus completing the cycle from man to man. It is believed that a certain percentage of cases of infection with intestinal parasites have their origin in this manner. Not only this, but it has been shown that flies developing from larvae which have fed on parasitic worms may harbor the immature forms of the parasites for several days in the intestinal tract, subsequently to scatter them broadcast.

A most interesting disease in which it is clearly established that flies act as the sole agent of transmission is sleeping sickness, this being an example of conveyance by inoculation. The infection is due to the invasion of the blood and body fluids by a parasite known as a trypanosome, which lives and multiplies

after it has once been introduced. Analogous parasites exist in the bodies of mammals other than man. Rats, for example, are frequently found to harbor a species of trypanosome, but curiously no symptoms develop. In this case the rat flea or rat louse is supposed to be the agent of transmission. A second variety of trypanosomes inhabits the blood of horses and other domesticated animals, producing a disease known as surra, an infection of serious economic importance in Asia, the Philippines, and other tropical countries. For many years the natives of India have ascribed the disease to the bites of insects, and at present it is all the more probable that certain species of bloodsucking flies are the responsible agents. Still another variety of trypanosome is seen in the horses, cattle, and domesticated animals of Africa. The disease as manifested in horses is known as nagana, and infected animals either die suddenly or are rendered useless to their owners as a result of deterioration through emaciation or weakness. Nagana is known to be transmitted by various species of biting flies.

In man, sleeping sickness, or trypanosomiasis, is a slowly fatal infection, recovery being very rare. The disease affects the natives of certain districts of central Africa, entire areas having been depopulated as a consequence of its ravages. It can be contracted only from a person harboring the parasites, but as the early stages of the infection are practically symptomless, frequent opportunities for its spread are afforded. The insect transmitter is a species of biting fly known as the tsetse-fly, which inhabits the shores of lakes and streams in that locality. Upon biting an infected person the insect absorbs the parasites, which then undergo certain changes within the body of the fly, and are subsequently inoculated into healthy persons, who, after a prolonged illness, ultimately die of the infection.

In addition to the diseases cited there are numerous other conditions where the possibility of fly transmission has at least been considered, although definite proof has been difficult to obtain of the truth of the theories advanced. In the majority of such conditions infective secretions capable of being transferred through the action of flies, either directly or through the medium of food, to healthy persons, are present. Tuberculosis may be mentioned as an example of such condition. Access to tuberculosis sputum by flies is not only disgusting from an aesthetic standpoint, but potentially, at least, of serious danger. The infectious disease of the eyes, trachoma, particularly as seen in Egypt, is unquestionably conveyed at times by these insects. Tropical sore, a serious and mutilating ulcerative disease occurring in various sections of South America, is not improbably disseminated by flies, and it is also believed that yaws, a somewhat similar disfiguring disease accompanied by infective secretions, may at times be spread in this manner. Mention should also be made of anthrax, which only occasionally affects man, but is rapidly fatal to cattle and sheep, and therefore of importance to the farmer. The spores of this organism are extremely difficult to kill, and it is believed that they may live in the intestinal tract of flies for days, to be later inoculated into healthy stock through the avenue of open sores or abrasions. Still another infectious disease propagated through the agency of flies is phlebotomous fever, found only in districts where that most pestiferous of all insects, the sand fly, abounds, and due directly to its bite.

Before the subject of disease transmission by flies is dismissed a remaining condition should be mentioned. This is myiasis, or, in other words, the invasion of wounds, body cavities, or the alimentary tract of man or animals by the larval forms of any species of fly. This condition, while rare where the ordinary rules of cleanliness are observed, is not at all unusual among those of filthy habits or those who are subject to neglect, more especially the residents of tropical countries. Of the cavities selected the ears and nose, particularly if abnormal secretions are present, are most apt to be the sites involved. Sleeping in exposed places accessible to insects predisposes to the condition. Neglected wounds, if accompanied by purulent discharges, may be the seat of lesions resulting from the activities of larvae developing from eggs deposited by the female fly. In the same manner larvae may develop in the alimentary tract of animals, and even of man, causing not only uncomfortable but serious symptoms. There are certain varieties of flies where a portion of the developmental cycle is ordinarily passed in the alimentary tract of animals, the eggs being deposited upon the hair. Upon the development of the larvae a slight amount of irritation results, which causes the animal to lick the spot, thus introducing the larvae into the stomach, where they attach themselves to the mucous membrane until they are ready for pupation.

Enemies of Flies.

Before consideration is given to the subject of fly control, brief mention should be made of the natural enemies of flies and the diseases from which they suffer, inasmuch as the number of insects is frequently affected through the operation of such causes. Unfortunately, the natural enemies are few and those which do exist are scarcely under the control of man. Among the enemies to be mentioned are lizards, toads, spiders, certain species of wasps, and robber flies, all of which devour flies whenever they approach within reach. The lizards and toads are particularly good flycatchers, but naturally the combined effect of all these enemies upon the total fly population is almost negligible. The enemies of the larvae are, however, much more successful in their inroads. First place should, of course, be given to the birds, which eagerly devour both the larval and adult forms. The scratching barnyard fowl is a worthy enemy, and certain forms of beetles and ants also feed industriously on both larvae and pupae of nearly all varieties. On the whole, the natural enemies of both the larval and adult forms fail to effect an appreciable reduction in the fly population.

The diseases of the fly family are seemingly much more deadly, but here again man is unable to take advantage of their presence. There are a number of parasites which are probably annoying to their hosts, but not especially destructive, and there are also certain mites which attach themselves to flies for migratory purposes. These are merely of scientific interest. Other parasites, including several species of worms, invade the internal organs. Altogether, the truth of the trite saying of Swift regarding fleas—

> So naturalists observe a flea
> Hath smaller fleas that on him prey;
> And these have smaller still to bite 'em,
> And so proceed ad infinitum.

is equally applicable to the various members of the fly family.

Adult flies are subject to at least one disease which makes serious inroads upon the insect population. Probably most of us have noticed late in the summer season dead house flies attached to ceilings or articles of furniture. Upon close inspection they may be found to have a whitish discoloration upon the abdomen or the entire fabric of the fly may appear disintegrated. The white material observed is the remains of a fungus known as the house-fly fungus or empusa. The fungus is more frequently observed in insects which have adopted an indoor life, but it also attacks those living under outside conditions. The disease is probably derived from insects similarly affected and first invades the body through either minute openings or the respiratory channels, gradually encroaching upon and destroying the internal organs and causing death within a few weeks of its appearance. The infection is especially prevalent from August to October and accounts, in large part, for the great reduction in the number of flies during the latter part of the season, literally millions of insects being destroyed at this period. It is a matter of regret that the disease does not manifest itself earlier in the season and that it is a condition as yet beyond the control of man, otherwise the fly problem might be capable of easy solution.

Eradicative Measures.

The most successful method of ridding a community of flies is to institute a continued campaign for that purpose. It is only by the united efforts of all residents, supplemented by the support of the health department and civic organizations in general, that progress in fly eradication is possible. This does not mean that individual effort is to be entirely subordinated or submerged, or that cleanliness of single premises is not of value, but only that the problem should be attacked as a whole and that the united effort of every citizen is necessary for its solution. When this is obtained, and the measures for fly prevention are carefully outlined, the actual work may be undertaken.

The time of the year has an important bearing upon the success of such a movement. Ordinarily fly-eradicative campaigns are instituted too late in the season to be effective. The best results are obtained if the work is begun in April, or in southern latitudes even in March, and not postponed until the natural increase in the fly population renders eradicative measures futile. The chances of success of any campaign diminish rapidly as the summer months pass. Fly prevention is much more successful than fly eradication, and this aspect of the question should constantly be borne in mind.

Of the measures to be recommended, those which aim to control the development of the larvae hold first rank, while those instituted against adult flies are usually far less successful. As long as fly-breeding areas exist it is useless to undertake suppressive measures of other character; therefore effectual control of these places is the first requisite. This means that the highest standards of community cleanliness must prevail, that accumulations of refuse and rubbish must be avoided, and that proper disposal of garbage and waste must be provided. When it is realized that even small amounts of material of this nature may serve for the development of innumerable larvae, the importance of its removal can be realized.

As horse manure constitutes the favorite breeding place for flies, its pro-

tection from adult insects is essential. Provision should be made in stables for its reception in either closed or screened bins, preferably the former. These bins should be made of cement or wood and should be properly drained in order to avoid the development of unpleasant odors. Where a small amount of manure is handled covered cans may be used. For large manure heaps the form of larval trap consisting of a raised platform a foot or more in height, covered only with slats, has been recommended. Beneath the platform is a concrete tank, holding about 2 inches of water, with plugged inflow and outflow pipes. The manure is placed on the slats and is entirely accessible to flies, but when the larvae reach the migratory stage they leave the manure, fall into the water, and are drowned. The cement basin should be flushed out at least twice a week for purposes of cleanliness and to prevent the breeding of mosquitoes, and the manure should be kept fairly moist. It is estimated that fully 99 per cent of the developing larvae may be killed in this manner.

On the farm the problem of manure disposal is not at all simple. Accumulations of animal excreta are largely unavoidable and flies even may breed in manure distributed on the soil for fertilizing purposes, although if the material is well pulverized this is less likely to occur. Where it is impossible to properly protect manure piles, treatment with certain vegetable and chemical products, with the idea of destroying both the eggs and larvae, is to be recommended. Of such substances, borax is probably the best, applied either in solution or sprinkled over the manure and then moistened with water. The development of both the eggs and the larvae is inhibited. Unfortunately, the borax contained in manure so treated may injure certain soils, especially if used in an excessive amount; therefore the quantity should not be too liberal. The Department of Agriculture estimates that if the amount does not exceed 1 pound to every 16 cubic feet of manure and that if not more than 15 tons of the treated material is applied to the acre no damage will result. There are a number of other substances adapted to this same purpose. Chloride of lime, or bleaching powder, if applied in liberal quantities, not only prevents access of flies but also the development of the larvae. However, it is directly injurious to the manure, as it interferes with its fertilizing power. If used, the dry powder should be sprinkled upon the mass. Hellebore, also used for the destruction of potato bugs, is fairly efficient. For every bushel of manure an ounce of the powder should be mixed with 1 gallon of water, and after standing for a day or two sprinkled on the pile. Another substance which has been used with beneficial results is sulphate of iron, 2 pounds per gallon of water, this being sufficient to properly treat the manure from one horse for a day. Kerosene, which has had extensive use for this purpose, has but little effect upon the fly larvae and is decidedly injurious to the manure.

If manure can neither be protected nor treated, its frequent removal becomes necessary. Under ordinary conditions the entire life cycle of the fly occupies only eight or nine days, but from the time the egg is deposited until the larval migratory stage is reached but four days are required. For this reason it is essential that the manure be removed at least every four days if fly breeding is to be prevented. The same rule applies to collections of refuse, organic waste, decaying vegetable matter, and street sweepings. If material of

this nature remains exposed for a longer period than four days it necessarily becomes a breeding spot for flies. Its removal and early destruction is therefore to be urged. While fairly good results may attend the treatment of organic wastes and refuse in a similar manner as that recommended for manure, it would be quite unwise to adopt such a course when more practicable measures are at hand.

Next to stable manure the outhouse or privy of rural communities deserves attention. House flies which develop in or frequent human excrement are many times more dangerous than those which frequent other filthy areas; therefore every effort should be made to eliminate this particular source of flies. Fortunately this is not a difficult procedure. While many types of sanitary privies have been devised (see Public Health Bulletins Nos. 51 and 68), all should have the one common provision of preventing the ingress of insects. This is best accomplished by screening. Every aperture should be thoroughly protected in this manner, and if openings exist either in the masonry or woodwork they should be closed. The seat should be self-closing, and if ventilating openings are present in the receptacle or other portion they should be properly screened. The same principles apply to latrines in camps or wherever human excrement is deposited.

The proper disposal of garbage has been already referred to. It is best that all household refuse be kept in water-tight metal cans having accurately-fitting lids, not only to prevent access of flies, but of other vermin as well. Collections of rubbish about the yard are responsible for much of the fly breeding, and public dumps may also constitute a prolific source of these insects. If these accumulations are permitted, fly breeding is inevitable.

Of the measures directed against adult flies, screening is most suitable. The unscreened house and the unprotected privy constitute a menace which no family should tolerate. It is of course well recognized that screens do not keep out all flies, but if the screening is properly done certainly 95 per cent of flies are prevented from entering and the danger is therefore reduced by just that percentage. If the owner is unable to protect the entire house in this manner, the lower floor should be given the preference, principally because flies are most numerous at that level, and it is the place where food is prepared. If not more than one or two rooms are to be screened, the kitchen and dining-room should be selected. In the case of sickness the sick room should by all means be protected, particularly if the disease is infectious, and in farming communities the dairy should receive similar attention. For persons sleeping out-of-doors where flies abound, screening is not inadvisable. It is also just as necessary that flies should not have access to markets, bakeries, and other places where food products are exposed. Whenever screening is instituted it should serve the double purpose of keeping out mosquitoes as well as flies; therefore a No. 16 mesh wire should be employed.

The devices for ridding rooms of flies are many, varying from traps, poisons and papers to fumigation. Most of these procedures are objectionable in one way of another and many are ineffective. The most common form of trap is the conical or cuboidal wire-gauze affair, baited with saccharine substances and arranged in such a manner that the insect passes through a small opening into

a large space from which he is unable to emerge. As traps go, they are generally effective, but flies, like all other animals, are often reluctant to enter places from which they can not escape.

Of substances poisonous to flies, formalin is perhaps most useful. It should be diluted with about 40 parts of water and placed in saucers about the room, at the same time removing all other liquids. After being denied all fluids for several hours the flies will drink the formalin solution and die, but the success of the plan is wholly dependent upon the complete removal of other liquids. A modification of this plan is to make the dilution with milk, placing a piece of bread in the saucer on which the flies may alight.

Of other fly poisons mention should be made, merely for the purpose of condemnation, of those composed of arsenic. Fatal cases of the poisoning of children through the use of such compounds are far too frequent, and owing to the resemblance of arsenical poisoning to summer diarrhea and cholera infantum, it is believed that the cases reported do not by any means comprise the total. Arsenical fly-destroying devices must therefore be rated as extremely dangerous and should never be used, even if other measures are not at hand.

Sticky fly papers are fairly efficacious in reducing the number of flies, even though they are not a mark of good housekeeping. They are, of course, disgusting to the eye and unless carefully handled serve to contaminate objects with which they come in contact. Fumigation with sulphur dioxide gas, generated by burning ordinary brimstone, is a valuable insecticidal measure, but unfortunately is injurious to fabrics and to painted and other surfaces. The sulphur should be used in quantities not less than 1 pound per 1000 cubic feet of space, moistened with alcohol, and ignited, care being taken that the metal container is placed in a pan of water. Pyrethrum, or insect powder, may also be burned, but it is expensive and only temporarily stupefies the insects.

Fly-swatting campaigns, of themselves, are not sufficient for the elimination of flies. Usually they are inaugurated only at the height of the fly season when a perceptible diminution in the number of insects present is not possible. If instituted during the early spring months, when the insects from which the millions of others are to be derived are few in number, some benefit may follow, particularly if precautionary measures are also exercised in regard to breeding places. If the energy displayed in late-season fly-killing campaigns could only be directed into proper channels during the early spring months, and if the people would realize that strict cleanliness and the immediate destruction of all filth and garbage are essential throughout the year, the fly problem would be largely solved.

THE HAWAIIAN PLANTERS' RECORD

Volume XXII. MAY, 1920 Number 5

A monthly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

Bud Selection. In this number we present two brief articles from a California journal, bearing on the improvement of the fruit orchards of that state through methods of bud selection. A third article on this phase of plant improvement is a report which Mr. A. D. Shamel has written as a result of his studies in Hawaii during the past few weeks. He deals with the question of isolating superior strains within our standard varieties of sugar cane, and presents his opinion as to the practicability of such an undertaking.

Some Facts About Citrus Bud Selection.*

By C. S. MILLIKEN.

Three years ago next May, the Fruit Growers Supply Company started the distribution of buds from superior citrus trees. Up to that time the selection of bud wood for propagation had been more or less casual. The results of Mr. Shamel's work demonstrated so forcefully the importance of bud selection, however, that the industry demanded more careful methods, so that at present some of the best groves in California have been selected, individual tree records kept, and the propagation bud wood is cut from these trees.

The object of this bud selection is not to create new citrus varieties. Its object is to take the very best in our present standard varieties and by budding from these sources, to make an improvement in our citrus plantings.

It is needless to say that bud selection is not the only important factor to be considered in the building of a productive orchard. Bud selection insures good parentage, but the offspring of good parents do not thrive unless they are properly nourished and grown in a salubrious environment. Bud selection is

*From The California Citrograph, May, 1920.

not a substitute for fertilization, irrigation, soil or climate. The point is that no matter how good the soil and climate, how pure the water, and how lavish the fertilization, productive trees cannot be grown from inferior parents.

There are many citrus growers who have discovered this in a very practical way—growers who have planted orchards propagated entirely from unproductive trees. After years of effort—fruitless effort—they are forced to rebud or to replant. Where good and poor trees are mixed throughout an orchard, as is most often the result of guess-work budding, the testimony of the unproductive trees is not so striking as where they happen to be segregated in unproductive blocks. Their effect upon returns is just as real, however, and if they could have been eliminated before planting, how different would be the record of the grove.

Bud selection should give us more productive orchards. What is the evidence? We will enter as exhibit one in the evidence, the young Lisbon lemon orchard at the Limoneira Ranch at Santa Paula. This orchard consists of trees in which there was a bud selection from the best trees in a good bearing orchard where individual tree records had been kept.

The older part of this young Lisbon orchard is now nearly seven years old, having been planted in the summer of 1913. In appearance it is one of the most uniform groves in the state, unquestionably the most uniform one that the writer has seen.

Individual tree records were not started in this orchard until June of 1917, when the trees were four years old. During the seven months of 1917, during which records were kept, the poorer lemon months of the year, the production averaged a picking box to the tree. The picking box holds about forty-three pounds of fruit. The next year, 1918, was the year of the hot spell which did so much damage to citrus crops. In 1918 these trees averaged two and three-fourths picking boxes per tree. In 1919 they averaged slightly over four picking boxes per tree. And it is to be remembered that Lisbon lemons have the reputation of being rather slow to come into bearing.[1]

The importance of bud selection is apt to be under-emphasized. To the average person an orange tree is an orange tree and a lemon tree is a lemon tree. It is generally known that in order to make these trees grow, they must be watered and fertililzed. But it is less generally known that in order that they may hang heavy with fruit of the desired type, they must have the right type of parent. The purpose of bud selection is to select parentage with care, a care in which guess-work judgment is replaced by a judgment based on accurately collected facts. The results of bud selection will be better orchards.

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[1] We are informed that the product of a four-year Lisbon tree from an unselected bud is not more than five pounds per tree; a seven-year tree, one picking box.—H. P. A.

The Improvement of Sugar Cane by Bud Selection.*

By A. D. Shamel.

In response to your invitation I have completed a preliminary field study of the possibilities of improving sugar cane varieties through bud selection. My coming to Hawaii for this purpose was made possible through the sympathetic attitude of officials of the Bureau of Plant Industry, in which organization I am employed, and the Secretary of Agriculture, who granted me a special furlough for this purpose, making an exception in this case to the rule that employees of the U. S. Department of Agriculture are not loaned to private institutions.

During my stay here I have been able to make an unusually careful study of the condition of bud variation in several sugar cane varieties as a basis for the work of the improvement of these varieties through bud selection, by reason of your active personal cooperation and through the keen interest and helpfulness of several of your associates.

Our work has been carried on in the field by means of performance record studies of the behavior of individual sugar cane stools growing under commercial conditions of culture.

In these studies small plots of sugar cane were selected where the conditions were apparently uniform and in which the individual stools were growing under comparative environmental conditions.

In these plots both plant cane and ratoon cane were studied. In some cases the stalks were about one and in other instances approximately two years old.

Owing to the short time available for this work, it seemed necessary to confine these detailed studies to one or two varieties of leading commercial importance. It seemed apparent that the results secured from such studies, from which conclusion could be drawn, would be typical of similar work with all of the varieties grown in Hawaii. The careful and systematic work with a few varieties was thought to be preferable to a more general and less careful study of a greater number of varieties and covering a greater area.

In the course of these studies, performance record plot and individual stool studies have been carried on with H 109, Yellow Caledonia, D 1135, Big Ribbon, and Striped Tip varieties.

For the most part these studies have consisted of securing and recording individual stool data under the following heads: number, length, circumference and volume of stalks, length and number of internodes, condition of buds, lalas and tassels, weight of stalks, weight of bagasse, weight of juice, Brix readings of the juice, weight of sugar, and other notes descriptive of the stool conditions. These data were secured for each stalk in each stool in the performance record plots.

The position of each stool and of each stalk in each stool has been charted on cross-section paper, in some of the performance record plots, in order to show

*From a letter to the Director of the Experiment Station, May 3, 1920.

the location of each stalk, the stand of stalks, the arrangement of stools, and other important conditions.

This work was carried on by several men, each having a particular duty to perform. The selection of the varieties for the purposes of this study, the location of the performance record plots, and the method of work were all agreed upon after careful consultation and consideration. In locating the plots all possible care was exercised to secure uniform environmental conditions, in order that the differences in stool behavior could reasonably be ascribed to inherent differences due to bud variation, rather than to apparent soil differences, cultural or other conditions of the environment. The method of study and of recording the data was evolved as a result of experience in these studies.

From the fact that for the past twenty-two years I have been engaged in similar work—four years in charge of corn and other crop-breeding investigations at the Illinois Agricultural Experiment Station, seven years in charge of tobacco, cotton, asparagus and other breeding work with plants commonly propagated from seed, and eleven years with the investigation of the conditions of bud variation as the basis for the improvement of citrus and deciduous fruits through bud selection for the U. S. Department of Agriculture—the method of study pursued in these sugar cane investigations has been that with which we have been able to secure important commercial results in our previous work.

The results of the studies in the sugar cane performance record plots will be published in detail by the H. S. P. A. Experiment Station as soon as the tabulation of the data secured in the course of this work can be completed. In this way the exact results of these investigations can be considered by those who are interested in them.

From the fact that the results of our investigation will be published at an early date, no attempt will be made at this time to present any of the details of this work. It seems desirable, however, to summarize some of the results of our investigation in order that you and others may consider our conclusions while they are fresh in the mind.

Bud variations and mutations are of common occurrence in the sugar cane varieties. This is an established fact. My attention was first called to this condition in 1915 through a reference to these phenomena by Dr. R. S. Norris, at the San Francisco meeting of the American Association for the Advancement of Science, during the discussion of my paper on "The Importance of Bud Variation and Bud Selection in the Work of Crop Improvement." At his suggestion I secured a copy of the book "Cane Sugar," by Noel Deerr, in which the subject of "Bud Sports" is discussed on pp. 23–38. Later, other publications were secured, including The West Indian Bulletin, Vol. 2, No. 3 (1901 or 1902), where, on pages 216–223, the subject of "Bud Variation in the Sugar Cane" is discussed. In these publications numerous instances of sugar cane varieties arising from bud variation are cited and descriptions of these varieties given. In these discussions the color variations arising from bud variations are mainly considered.

From all available information it seems apparent that many of the sugar cane varieties of commercial importance in the world have been secured through the selection and propagation of bud variations. The records show clearly that

improved varieties of cane have arisen from bud variations in Louisiana, the West Indies, Mauritius, Australia, Hawaii, and elsewhere.

All authorities on record agree that bud variations in sugar cane are quite common and that plants grown from cuttings of the bud sports tend to reproduce true to the character of the sports.

Our studies here agree with these conclusions. While previous studies seem to have been concerned mainly with color variations, our investigation has forced us to the conclusion that bud variations in the sugar cane are not confined to color characteristics, but are also quite common with regard to other physical and chemical characteristics of the plants. It seems likely that color changes are frequently correlated with the size of stalk, number of stalks in the stool, weight of sugar in the individual stalks, and in the stools as a whole.

From the data secured, the tabulations thus far made indicate certain correlations of appearance and sugar content. It seems probable that a selection of stalks and of stools can be made from appearance, which will also show marked differences in sugar content and other characteristics.

Starting with the established fact that bud variations are of common occurrence in sugar cane varieties, this condition furnishes the basis for two phases of work of very great commercial importance to the sugar industry, viz.: (1) the origination of new varieties through the selection and propagation of striking bud variations, and (2) the improvement of established varieties through the isolation and propagation of the most valuable strains by means of systematic bud selection.

The first phase of this work will not be discussed at this time. The second phase, which I consider to be of the greater commercial importance, will be considered very briefly in this letter.

Our studies have clearly shown that in the varieties observed diverse strains exist, which have arisen through bud variations. The inferior strains have been propagated unintentionally by planters. The lack of a practical method of seed selection whereby seed from the stools of the best strains could be secured and seed from the stools of the poorer strains avoided, has resulted in the propagation of the inferior strains along with the valuable ones.

My observation has been that without selection in the propagation of any plants the inferior strains gradually increase in proportion to the good ones until eventually the population of the fields is largely made up of the undesirable strains.

On the other hand, my experience has shown that, with selection and propagation of seed or buds secured from the superior plants, it is possible to improve varieties so that the total population of the fields is largely made up of uniformly good plants. In this way, the selection and propagation of the best individual plants, the production and the value of crops can be definitely increased and improved without any increase in the cost of production other than that incurred in securing the seed or the buds.

The improvement of established breeds of livestock, and of established varieties of plants propagated from seed, has been carried on with very great success for a long time through the selection and propagation of the superior individuals within the breeds or the varieties. I believe that it has been clearly demonstrated

that most of the commercial progress in the improvement of livestock and crops has been effected in this way.

The agricultural crops, in which the plants are propagated vegetatively, or from buds, cuttings or grafts, have not been improved in the same degree as have the established breeds of livestock or seed crops. It is my conviction that the improvement of vegetatively propagated crops is a full half century behind that of animals or seed plants. This condition exists, I believe, because of the lack of knowledge of the condition of bud variation in such plants and the absence of practicable methods of bud selection which will take advantage of the development of superior individuals which originate as bud variations or bud sports.

Not many years ago many scientific men believed that such improvement was impossible. Today, all of the leading geneticists agree that not only is such improvement possible, but that it is probably of much greater commercial importance than we can now realize with our present inadequate knowledge of the phenomena of bud behavior. Slowly but surely facts are being accumulated which indicate the best methods of using and controlling the variations arising from bud-propagated plants in order to increase and improve our food supply.

My conclusions as to the improvement of sugar cane varieties through bud selection are: (1) marked improvement can be effected in the production of sugar by the established varieties through the selection and propagation of the superior stools; (2) in this work the quantity of sugar produced by the individual stools in a given field and growing under fair comparative environmental conditions should be given primary consideration. While color changes and other characteristics are interesting and significant, I am firmly convinced that the selection of mother stools should be based primarily on the quantity of sugar that they develop under field conditions. It is apparent that the quantity of sugar developed by a stool is clearly correlated with the number, size and weight of the stalks constituting the stools. Therefore, it seems logical that the stools producing the most sugar can be selected by inspection, securing seed from the stools having the largest number of large and heavy stalks with high sugar content. A necessary corollary to this statement is that in securing seed all stools with a small number of stalks or possessing small or light stalks with low sugar content should be avoided when cutting seed cane; (3) in selecting stools for propagation only those having uniformly large heavy and desirable stalks should be selected for propagation. The importance of uniformity of stalks within the stool may not be fully appreciated without actual experience in this work. One may think of it from several points of view. For example, take a human family in which there are several children of uniformly healthy, strong and well developed appearance. It is apparent to every one that in such a family we have good parentage and strongly developed hereditary characteristics. In the same way, thinking of the stool of sugar cane as a family made up of several stalks, the importance of uniformly desirable stalks in this family indicates to my mind the fact that in this family there is good parentage with highly developed desirable hereditary traits that may be prepotent and be carried on to succeeding bud generations.

In our citrus studies in California, and particularly in the securing of com-

mercial supplies of bud wood for propagation, only those trees are selected as sources of bud wood which are known to produce uniformly good fruits. If at any time during the performance records of these trees a single variable or off-type fruit is observed, those trees showing this condition are discarded as sources of bud wood. The results of this care in the selection of bud wood from superior parent trees of oranges, lemons and grapefruit are shown in several thousands of acres of fruiting orchards possessing uniformly good trees which produce uniform crops of fruit. This improvement in production in the citrus crops in California has already meant millions of dollars to the growers, in the opinion of those who have participated in and benefited from this work.

Similar beneficial results from the selection of superior parent plants in those crops which are vegetatively propagated have been secured in potatoes, a crop which in many ways, and particularly from the viewpoint of method of propagation, closely resembles the sugar cane. These results have been clearly established and demonstrated experimentally at the Cornell Experiment Station and commercially through the experience of many growers. For example, Lon D. Sweet, of Carbondale, Colorado, an extensive commercial grower of potatoes, has been able within a few years to improve the production of his Burbank variety, through the selection of uniformly good hills for seed, to the point where the value of his crop has been increased more than fifty per cent by reason of uniform size of tubers, and at the same time the quantity of tubers has increased more than fifty per cent by reason of the elimination of the poor hills. In other words, he has been able to increase the value of his crop more than one hundred per cent through the systematic selection of uniformly good hills for seed purposes.

In these investigations, seed cane has been secured and planted from both good and poor stools in each of the varieties studied. The behavior of the progenies will demonstrate the relative importance of some of the strains in each variety and the necessity for care in securing seed cane for propagation. A sufficiently large number of propagations have been made to show at an early date the possibilities of this work. Further selections should be made as opportunity permits in different locations, with more plantations, and with other varieties, in order that all of the facts be ascertained.

The commercial application of the principles of seed cane selection developed during the course of these studies include, in my opinion, the following considerations: (1) The selection of stools for propagation must be made by men with trained practical sugar cane experience and an intimate knowledge of the variety and its plant characteristics, gained from actual and first-hand work with the plants themselves. These men should have the farm point of view, which includes a quick realization of the economic side of farming. They should be careful and keen observers, who will develop that enthusiasm which will lead them to untiring effort in their field work. The importance of this work is such that, in my opinion, men can well afford to devote their lives to its study in order that they may become competent, truly expert, and achieve lasting and beneficent results for the sugar industry. (2) The work should largely be done in the field. No other methods of study will give really important economic results. From the fact that it is pioneer work, little or no published data is at hand concerning it. Therefore, it cannot be carried on from books; it must be done at first-hand

with the plants themselves. The men who are engaged must realize from the beginning the importance of serious, steady, and sustained effort. Like all other pioneer projects, its development will likely be attended with some difficulties. This condition seems to be a wise provision of nature to separate the weak and incompetent from the strong and competent. Valuable and lasting results are never easily achieved. They are the reward of patient, conscientious, enthusiastic, and sustained effort.

(3) Two kinds of work should be carried on. The experimental work, where the behavior of selections under comparative conditions can be studied, should be largely segregated and not be confused with the practical field work. This work can probably best be done in some of your Experiment Station fields. The selection of superior stools for propagation commercially should be done

Not more than two or three stools out of one hundred were suitable for seed purposes.

on each plantation. In this work it may be advisable from time to time to introduce seed from one plantation to another or from one district to another. In my opinion, such changes should only be made after the most careful consideration of all factors involved, although it may eventually become desirable to maintain seed fields in some districts of small plantations where reliable seed can be secured for planting by several planters.

(4) The securing of seed from superior stools should be done by those trained in this work. It seems likely that after standards are developed for the different conditions, many intelligent plantation laborers can be used for this purpose. Sufficient seed cane should be secured from the superior stools to plant an adequate mother field. This mother field, planted from the seed cane of the best stools in the established fields, can then be used for securing seed for general planting. It seems likely that if the first selection is carefully made, in which

probably less than one per cent of the total number of the stools in the fields are selected for propagation, the securing of commercial seed from the mother fields will be a relatively simple matter. A large percentage of the stools in the mother fields ought to be suitable for propagation. A gang of seed cutters can probably go through the mother fields and cut the seed from the good stools, avoiding only those showing markedly undesirable characteristics.

In the course of the study of both the general and the mother fields it is likely that a very few particularly superior, heavy, and desirable stools will be found. The seed from these distinctly superior stools should be carefully planted in a location where the behavior of the progeny can be closely watched, with a view to developing better strains.

I would like to recommend that when conditions warrant, a separate project be organized in the H. S. P. A. Experiment Station for the improvement of sugar cane through bud selection. This project should include both the experimental work and the commercial application of this work. The two lines should be kept separate, but yet carried on in one project, in order that both receive the benefit of the experience secured in the two lines of work. The men carrying on this work should do it exclusively, so far as possible, and be relieved of other duties which might interfere with the proper development of this project. Concentrated and continuous effort will be required during the entire year if the project is to be made a vital and necessary part of plantation practice.

The logical development of this project is likely to lead to other important and beneficial contributions to plantation practices in addition to that of seed selection. In the citrus, as a result of our bud selection studies, and based largely upon them, we have been able to discover fundamentally important methods of practice which are almost equal in importance to the bud selection work itself. I refer particularly to our study of the behavior of pruned and unpruned trees, and those pruned by different methods. This work was carried on as a part of our individual-tree performance-record work, and the results were such that they vitally affected commercially the practice of pruning in every citrus orchard in the state. Again, in the course of our work, the care of our trees in the performance-record plots led to the discovery and introduction of an improved method of applying manure to the soil, commonly called the furrow-manure method. At a recent conference of citrus growers, held in San Bernardino, California, February 20, 1920, the statement was made by one of the leading growers that the use of this method in California citrus orchards the past year was clearly responsible for the saving of one million dollars worth of plant food in the manure applied. Several other equally important results arising from these careful field studies could be mentioned, but the above are sufficient to show something of the possibilities of these first-hand studies, systematically carried on by sympathetic workers during a period of years.

(5) No public campaign of education seems necessary in the development of this project. The results speak for themselves. For example, let any plantation manager or other interested person cut one hundred successive stools from his best field, taking care to keep the stalks of each stool together. Lay these

stools out side by side, but distinct from each other, on a clear space where they can be examined. Go over these one hundred stools carefully and determine the number which from any point of view are apparently desirable for seed. In our studies these demonstrations have been particularly convincing. They have been carried on with one-year and with two-year-old stools, with plant cane and with ratoon cane. In any of the numerous cases studied thus far not more than two or three stools out of one hundred were suitable for seed purposes. Even the veriest novice must be led to this conclusion during such tests.

The mother fields should be, and I am confident will be, the strongest possible argument for care in seed selection. My observation is that farmers are intelligent men, more intelligent than they are usually given credit for being by those who do not till the soil. In fact I believe firmly that they are above the average in intelligence. My further experience is that when once a better method of growing crops has been clearly demonstrated for their particular conditions, they will quickly adopt such methods and make them a part of their regular operations. This particular work will demonstrate itself, and I am confident that amongst your plantation operators some men will contribute the most valuable information leading to its development and improvement, as has been the case with every other agricultural industry with which I have been identified.

(6) The exact methods of procedure will develop with experience. For example, the standards for stool selection, the number of stalks, their size and other characteristics, will likely differ in different regions having particular varieties, soil, cultural and other conditions of culture. The perfection of methods of selection is a matter of growth which will take care of itself if the necessary hard work, both physical and mental, is performed. The object of the work is clearly the improvement in production of sugar through the propagation of the superior strains and the elimination of the undesirable ones, through systematic seed selection from superior stools. If this ideal is kept clearly and continually in mind the results will come without question in my mind.

(7) The first selection is of the greatest possible importance. In my work so far I have observed that the greatest step was the first one. For example, in the isolation of strains of tobacco for growing under shade in the Connecticut Valley in 1903, one strain was fully isolated, which is now universally grown under the 10,000 acres of tobacco tent shade in that district. Another strain was isolated at that time, which is now universally grown under shade in Florida and Georgia. No similarly important steps have been made since, although great efforts have been made along this line. Similarly, in the isolation of the best strains of orange, lemon and grapefruit varieties in California, the director of the Citrus Experiment Station and others have repeatedly offered their opinion to me that the greatest step has been made that is likely to be achieved for many years, if ever. Therefore, in view of these and other similar experiences, it seems highly desirable to exercise the greatest possible care in making the first stool selections with sugar cane.

(8) Variation is continuous. This is one of the irrefutable facts in nature. While in the isolation of superior strains by the first selection of stools I believe that the greatest step will be made, I do not mean to convey the idea that the necessity for selection will stop there. Far from it! Experience in the development of strains of animals and plants shows unmistakably that continuous selection is necessary in order to maintain and improve the superior strains. However, after the strains of sugar cane have been isolated through selection, the work of selection within the strains is comparatively simple and practicable.

(9) In this work I cannot see how any loss is possible. If the best stools on a plantation are propagated on that plantation it is apparent to every thinking person that there is absolutely no possibility of loss, other than the small cost of making the selection. On the other hand, there is every probability of a large gain through more uniformly good stools from the superior parent stools propagated for the fields. The full force of the above statements can only be appreciated from an inspection of stools under field conditions as they now exist.

(10) A selection of individual large stalks will not secure the results. In many stools we find one large, heavy stalk and several small, light and inferior ones. It is apparent to any experienced person that the seed from the single large stalk in a generally inferior stool is not as desirable as the selection of seed from several uniformly large and good stalks in the same stool. Even if there is only one decidedly inferior stalk amongst several good ones in a stool, the seed from the good stalks is not likely to be as good as that from uniformly good stalks.

(11) This project can be carried out in Hawaii, where the industry is an organized one, much more efficiently than if the industry was in an unorganized condition. This phase is particularly apparent to those who have worked with both organized and unorganized agricultural industries. With an organized industry, such as the Hawaiian sugar industry, this work can be carried on quietly and efficiently. With unorganized industries much motion is lost in the effort to bring the results of any endeavor to the attention of the many individuals in it. Therefore, I believe that this work can be done in a business-like way here and with the greatest possible good with the maximum economy of effort.

(12) The expense of this project is likely to be very small in comparison with its results, from many points of view. In the citrus industry we have carried on our work with a very small cost, owing to the fact that the growers have furnished us every facility—including labor—without cost. This generous cooperation and spirit of contributing something to the welfare of an industry is not, I feel sure, confined to California citrus growers. From our limited experience with Hawaiian sugar cane planters, I am satisfied that they will respond quickly and generously to the appeal of this work, as a matter of public service, as the citrus growers have done. We have had the active help for days at a time of plantation managers, who have helped study stools of cane and who have shown unmistakably that they are willing and anxious to cooperate in this work to the fullest possible extent. All of such indications point to the fact that this project can be carried on with a minimum of cost as a whole. At the same time

the importance of this work should not be jeopardized by any false economy. The men engaged in carrying on this work should receive liberal salaries, such as is justified by the beneficial results of their efforts, which will be almost immediate and of larger consequence than may be realized at the present moment. Such men will develop a definite knowledge and technique which must be compensated for, as it is in other professions, by adequate salaries.

Personally, I want to express my sincere appreciation for your sympathetic cooperation in this investigation and the assistance rendered by your associates in carrying on this study. . . . .

I would like to close this letter by quoting from another letter, dated March 23, 1920, and which reached me after I had been in Honolulu about one month. It is from a gentleman who recently passed his eighty-seventh milestone. He is generally known in Southern California as the Dean of the Citrus Industry. Ethan Allen Chase was born in Maine, but at an early age went west to Rochester, New York. At Rochester he founded the Chase Brothers Nursery, and was one of the main factors in making Rochester the nursery center of America for more than half a century. He organized, in addition to his New York nurseries, similar institutions in Alabama and California. No one man has had more to do with the commercial development of our deciduous and citrus industries than Mr. Chase. He is a conservative man of unquestioned integrity, broad experience and successful endeavor. For the past twenty-five years he has made his home at Riverside, California. When I first came to California, in April, 1909, I began our first citrus bud variation and bud selection studies in some of his valuable orchards. Since then I have had almost daily contact with this noble and illustrious man. I give these facts in order that you may appreciate more fully the section of his letter which I now quote: ". . . I have no doubt you will get very much interested in the work (bud variation and bud selection with sugar cane), and there is not a particle of doubt but that you will find certain canes worth double others. The same is true in all vegetable, animal, and tree worlds. When I was a boy a cow was just a cow. We now know one cow is often worth two, producing better stock, more butter fat. In these times a poor cow has not much chance in a dairy. I believe that there is not a fruit producer of any kind that has not good strains and poor strains—currants, blackberries, grapevines, etc. You will find the same in what you are now looking for. Strange that when you first began to search for best citrus strains here men calling themselves scientists had no faith in it. But they have all had to give up. What a vast pile of work to find all the prolific plants and trees and the choicest of everything, and how strange that so very little has been accomplished through the centuries and that the truth of it should not have been realized till this day and generation."—(Signed) *E. A. Chase.*

This experience and opinion from one of the ablest and keenest men in all agriculture, who has achieved such lasting results for the development of the great fruit industries of America, is worthy of every man's thoughtful considera-

tion. For my part, I am absolutely convinced of the possibility of improving your sugar cane varieties through bud selection. It is practicable and can be made of immense economic importance to the sugar industry.

An Expansion of Bud Selection Work in California.

As evidence of the growing belief that crop improvement through bud selection is applicable to many species of plants, we learn from the California Citrograph that this work is now to be applied to a wide range of deciduous fruits. We read:

"The California Nurserymen's Association has become so impressed with the advantages of bud selection, largely through the work which has been inaugurated by A. D. Shamel of the U. S. Department of Agriculture in the citrus industry, that it has instituted a similar movement as applied to all nursery stock. . . . . For the first season the work will be confined chiefly to apples, peaches, prunes, cherries, plums, pears, apricots and almonds; and . . . . as there are practically no performance record trees available, ... during the early years bud wood will be cut simply from selected trees in bearing orchards. Commercial performance record work will be started just as soon as possible, so that eventually all bud wood sold by the association will be from record trees.

"Another line of work which this association will carry on will be the gradual elimination of some of the less desirable varieties of trees, so that a short list of acceptable varieties shall be agreed on as typical standard species. The association is also to set aside a fund for purely investigational work so that the services of such men as Mr. Shamel shall be available during the summer months. Questions of strains will be studied, and investigational work very similar to that conducted by Mr. Shamel in connection with citrus fruit improvement will be carried on.

"The California Nurserymen's Association is certainly to be congratulated upon its pioneer effort in this line. The money and effort will be well repaid and great good will come to the pomological and horticultural interests of California.

"The citrus fruit industry blazed the way and will always stand out as the leader in this fine undertaking."

[H. P. A.]

Progress in Sugar House Methods in Hawaiian Sugar Factories. *

By J. N. S. WILLIAMS.

Hawaiian sugar factories are noted for the keenness with which improvements in manufacture and production, whether original or acquired, have been put into effect. This is especially to be noted in connection with methods of extraction of sugar from the cane, in methods of producing commercial sugars, and in handling after products.

The most striking advances made in recent years have been in the direction of the extraction of sugar from the cane. The introduction of the Messchaert Groove in 1914, which is now generally used throughout this Territory, marked a period since which the advances made have been almost phenomenal. Previous to 1914 extractions of 96% or over were very uncommon, but in the year 1919 there were more extractions of 98% and 99% than there were in the year 1913 of 96%, and this advance in six years, to say the least, is very remarkable.

Interest having been centered on the subject of extraction, the losses in final molasses have not received so much expert attention, but nevertheless considerable progress has been made. In the report of the Committee on Manufacture for the year 1905, mention is made that Dr. Maxwell, the first Director of the Experiment Station of the Hawaiian Sugar Planters' Association, in his report for the crop of 1896, stated that an average of twenty plantations then reported upon produced a final molasses having a direct polarization of 35.4% and 46.5% apparent purity. In 1905 the average point to which waste molasses had been reduced was 30.14% direct polarization and 34.3% apparent purity, and this marked a very considerable improvement over what had taken place in previous years. As soon as competent attention was directed to the subject it was found that the purity of the final molasses, calculated from the direct single polarization and the Brix reading of the molasses, was not correct; the true percentage of sugar in final molasses, and also the true purity, was determined, and the following true purities were given in the Annual Synopsis of Mill Data made up and issued by the Experiment Station, H.S.P.A., in the following years:

In the	year	1907	the	true	purity	of final	molasses	averaged	42.65%
"	"	1908	"	"	"	"	"	"	44.00%
"	"	1909	"	"	"	"	"	"	43.74%
"	"	1910	"	"	"	"	"	"	44.83%

Comparatively few of the plantations, however, had the facilities whereby the average true purity of all the molasses thrown out during the crop could be made, and for the years 1911, 1912, and 1913 these averages are not given in the Annual Statements.

During this time a comparative figure which represented the true figure was developed by Mr. Noel Deerr, and is known by the term "Gravity Purity." This

* A paper presented at a special meeting of the Hawaiian Chemists' Association, April 15, 1920.

figure is determined by ascertaining the pure sugar in the final molasses by the Clerget method of double polarization, and the density of the molasses itself by the fractional method of spindling. These figures for gravity purity are shown as follows:

For the	year	1914,	Gravity	Purity	of avge.	Final	Molasses	....40.40%
"	"	1915,	"	"	"	"	"	....39.69%
"	"	1916,	"	"	"	"	"	....39.25%
"	"	1917,	"	"	"	"	"	....40.03%
"	"	1918,	"	"	"	"	"	....39.07%
"	"	1919,	"	"	"	"	"	....37.95%

Most plantations now render their accounts for the quality of the final molasses on the basis of gravity purity, and the above averages are taken from the results of some forty factories.

For the year 1914 the average of 40.40% given in the above table is made up of a maximum gravity purity of 44.9% and a minimum gravity purity of 36.32%, the difference between the maximum and minimum being 8.58 points; for the year 1919, when the average was 37.95%, the maximum was 43.06% while the minimum was 34.32%, showing a difference between the maximum and minimum of 9.28 points, which indicates that while some plantations had made practically no improvement in the work others had improved considerably.

On referring again to the 1905 report of the Committee on Manufacture, it will be found that very little was known then about laws which govern crystallization in low grade massecuites, but that it had been found that the apparent purity of tank massecuites should not be less than 45, and that the density to which the massecuites should be boiled should be high. Figures deduced from the results of crop 1905 at the Hawaiian Commercial Sugar Co.'s factory at Puunene show that the recovery of sugar from a massecuite varied with the density, and when the density was low (from 88 to 90 Brix) with an apparent purity of 44% to 46%, the sugar recovered from such massecuites would be considerably less than when the density to which the massecuite was boiled was from 94% to 96% Brix; which discloses the fact that even as long ago as 1905 it was known that the heavier low grade massecuites were boiled the greater was the yield of sugar, provided always that the grain was of such size and regularity that such massecuites could be dried and the sugar recovered.

In 1906 an attempt was made to increase yields of sugar from final massecuites by so treating the molasses mechanically that a large proportion of the gums which accumulate in end-products during factory operations are removed. After considerable experimenting it was found that while it was possible mechanically to remove these gums, and thereby increase the apparent purity of the molasses operated upon, no financial results were obtained by reason of any increase in the amount of sugar obtained from such massecuites, although it was noted at the time that molasses so treated, boiled more freely, grained more rapidly, and dried more easily in the centrifugals, but these advantages did not appear then to be commensurate with the expense involved in improving the quality of the molasses above mentioned, and therefore these experiments came to naught. Similar experience on similar lines was gained in Porto Rico at the Central Guanica, and more recently experiments have been made on these lines

in this Territory in connection with the clarification of mill juices, which have likewise yielded no material benefits.

During the year 1914 it was discovered that a so-called final molasses of low purity (38%-42% gravity purity), if boiled to a density of 98% to 100% Brix, developed as it cooled in tanks or cooler cars an immense number of very small grains of sugar. This seemed to indicate a field of original research, and a good deal of work was done, the results of which were reported upon in a paper read at the Annual Meeting of the Hawaiian Sugar Planters' Association in 1916, which gave the results of certain experiments and set forth a theory that it was not the gums or other substances in the molasses resulting from the manufacture of cane sugar which prevented the pure sugar in that molasses from crystallizing out, but the presence of water in the molasses, which retained the sugar in solution. This theory has been energetically attacked by foreign authorities, and an animated correspondence in the columns of the International Sugar Journal was carried on for some time; the question is yet debatable as to whether or not the said theory is strictly or only partially correct. That there is foundation for such theory is shown by the following facts:

Since 1914 a number of plantations have adopted the plan of boiling final massecuites to a density of from 96% up, running the charge so boiled into crystallizers or tanks to allow of graining, and when these massecuites are ready for purging they are passed through a pug mill and thinned down with a dilute solution of final molasses, and thereafter dried in the ordinary way in the ordinary centrifugal machine. This in many cases has produced an average final molasses of very low purity, as shown by the returns in the Annual Synopsis of Mill Data issued by the Experiment Station of the Hawaiian Sugar Planters' Association.

A further advance on this line has been developed by the Technical Staff of the Hawaiian Sugar Planters' Association, and consists in boiling very low grade molasses to a low water content and seeding the massecuites with a proportion of exceedingly fine grained sugar, whereby crystallization in this low grade massecuite is stimulated and expedited. This massecuite, however, is of such consistency, and the crystals of sugar are so minute, as to practically preclude the recovery of the said crystals by any machinery in general use at the present time. Small samples of final molasses from such massecuites have been obtained, which are practically free from crystals, and, as might be expected, the gravity purity of such molasses has been reduced considerably below anything hitherto known.

A sufficient amount of massecuite having been prepared at the Experiment Station, it was put through a special machine, with the result that nearly 50% of the pure sugar present in the original massecuite was recovered in the form of a dense high-purity massecuite, which is of a sufficiently high purity to allow remelting and working back with No. 1 massecuites. The density of the massecuite operated upon was 99.1 Brix, it had a purity of 44.5%, and was made from final molasses from a number of plantations which had a gravity purity of 35%, a sufficient amount of very finely grained sugar being added to bring it up to 44.5% gravity purity. The final molasses which was taken off was of a density of 88.55 Brix and had a gravity purity of 31.98, while the valuable massecuite remaining had a Brix of 96.7% and a gravity purity of 68.34. The

exact figures in connection with this test are being developed by the Technical Staff of the Experiment Station, but sufficient has been said to show that progress is indicated.

Great strides have been made in our factory work for many years, and many minds have been, and are, at work on the problem of securing sugar now lost in our by-products.

Whether or no we have arrived at a solution of the difficulties which beset us we cannot say, but at least we can assure ourselves that we are fairly on the way towards securing further gains of sugar now lost.

Seedling Sugarcanes.*

In his presidential address to the Royal Agricultural and Commercial Society of British Guiana, Professor J. B. Harrison, C.M.G., M.A., discussed the general outlook as regards seedling sugarcanes, with especial reference to their stability, and the manner in which their production is best undertaken. These remarks, embodying as they do the expericence of one of the principal workers in this field of inquiry, extending over the whole period since the simultaneous discovery in the West Indies and Java of the seminal fertility of the sugarcane, carry very great weight; they are accordingly here reproduced in order to extend the publicity given to them. Professor Harrison said:

"In 1897 investigators generally were of the opinion that once a new variety of sugarcane was produced, that after its first period of excessive vegetative vigor had passed, its characteristics were fixed for all time. Soon after the cultivation of the new varieties had been extended over large areas, it became painfully evident to the majority of planters that their characteristics are not fixed, and that in many instances, characteristics which in the earlier years promised to make a variety of sugarcane of high value both in field and factory, were the first to fail. This tendency towards senile degeneration renders it necessary to raise new varieties of seedling canes year after year, in the hope of having fairly good varieties available to replace others which may gradually fail.

"Experience has proved to us that it is very easy indeed to raise new varieties of sugarcanes which are of high promise as plant canes. It has further proved to us that it is relatively difficult to obtain sugarcanes capable of producing good crops as plant canes and as first ratoons; and that it is exceedingly difficult to produce varieties which can be relied on to give satisfactory crops of plant canes, first, second, and third ratoons. Few indeed of the enormous numbers of new varieties which are now raised each year in various parts of the tropics will do this, and the problem of getting good varieties for cultivation under the long-ratooning system necessitated here by our deficient labor-supply and dependence on hand, instead of on mechanical, cultivation, becomes an exceedingly difficult one.

*Reprinted from Agricultural News, Vol. XVII, Sept. 21, 1918.

Elsewhere, with the exception of Cuba, sugarcanes are as a rule only cultivated as plants, or as plants and first ratoons. Hence, as the best varieties raised in Barbados, Java, and Hawaii have been chosen for their suitability for short ratooning periods, it is rarely that a sugarcane suitable for our long-ratooning conditions can be imported from elsewhere.

"The most successful method we have tried here for raising new varieties of sugarcane of promise is based on the facts that a sugarcane for successful cultivation on our heavy clay soils must be of well-marked vegetative vigor, and that whilst the range of variation in the saccharine-content of seedling sugarcanes is very great, its relative sugar-content is a fairly fixed characteristic of any variety. We endeavor to raise as many seedlings as we can from varieties of proved vegetative vigor, and select from them those having both well-marked vegetative vigor and relatively high saccharine-content. By this method we raised from D.625 the seedlings D.118 and D.419, the areas under which have increased from 2 acres and 1 acre, respectively, for the crop of 1911-12, to 2,710 and 1,360 acres, respectively, for this year's reaping.

"We have been advised time after time to give up our proven methods and to confine our efforts towards raising canes by cross-fertilization. If we had in this colony sugarcanes of single parentage showing fixed characters and, through their purity of origin, having little or no tendency to mutation or sporting, that advice would be excellent. In India, and to less extent in Java, sugarcane varieties of high purity of strain exist; and with these it is possible that by the application of Mendelian principles in raising seedlings, new varieties of high value may be obtained. Up to the present, however, this has not taken place.

"At the inception of the sugarcane breeding work here, Jenman was enthusiastic over the possibilities of raising new varieties of high promise by controlled methods of cross-fertilization, but in 1892-93 our hopes in that direction received a severe shock. Using a variety of sugarcane, the Kara-kara-wa cane, which our experience in three preceding years had shown to produce seedling canes having usually somewhat close resemblance to the parent variety, and placing it under conditions by which it was impossible for its arrow or flowering shoot to be either cross-fertilized by any other variety, or fertilized by any other flower shoot of its own kind, we got seedling canes from one arrow of 267 different sorts. The parent cane in its own seedling stage was hence possibly derived from fourteen diverse ancestral strains.

Supposing, for example, we take two kinds of sugarcane, one, X, having as ancestral kinds the varieties A, B, C, D, E and F, and the other, Y, derived from its ancestors A, B, G, H, I and J, it is evident that 406 different combinations can arise from the interbreeding of the two kinds, instead of a single blend or cross, X x Y.

"By Mendelian segregation, the inheritable properties of this diverse progeny will fall into three groups. We do not know which properties are inherited; but assuming that the general characteristics as a whole are heritable, the segregation of the seedlings from the cross X and Y may give rise in the first generation to 1,218 *groups* of varieties.

"Now either X or Y, by interbreeding with its own kind, could produce only 15x3 groups or forty-five general strains of sugarcanes. The complexity intro-

duced by the cross-fertilization of existent complex hybrids is well illustrated by this example.

"Up to 1902 we had not made any systematic attempt at raising canes of controlled parentage. We now do it as a matter of regular routine—not with any idea of getting seedlings having definite and desired characteristics, but as a means of greatly widening the range of their variation. We have complete proof of the success of the method in this line. Unfortunately, there is no chance in British Guiana of controlled cross-fertilization of the sugarcane proving a short and certain way to success in the production of new varieties of high saccharine value.

"Probably a more disappointing investigation has never been pursued than has been the search for improved varieties of sugarcane. There are now many stations at work at it in the tropics and sub-tropics; their results appear to be very similar. In the earlier years, working with natural varieties of sugarcane, several kinds of high promise are almost invariably obtained; in later years, when the mass of material for parental purposes has rapidly and enormously increased, the production of really good varieties appears to become increasingly difficult, and results satisfactory to both investigator and planter tend to be few and far between. It looks as though the good results arose from the unraveling of the complex ancestry of the natural varieties, whilst similar results from the re-tangling of the new strains thus obtained are comparatively rare, and are very elusive."

Those who are interested in the introduction of new seedling canes into their fields will, doubtless, in the light of these remarks, carefully consider the results which they are obtaining from their efforts. It will be observed that, in Professor Harrison's view, the work of finding promising seedlings is much more difficult when it is required to have canes that will ratoon well; when plant canes only are grown, the problem is relatively simple.

The question of the stability of seedling canes propagated by cuttings has long been under investigation. Some have held that these canes would prove stable, and indeed in the early days of the work this was the commonly accepted view; now, however, many are doubting this, and Professor Harrison appears to be amongst those who are convinced of the tendency towards early senile degeneracy on the part of these seedlings. It is observed that, in some districts where sugarcane is cultivated, there is a tendency to substitute one new seedling after another in the hope of obtaining ever increasing yields. Where adequate records exist, it would be well to examine these carefully, in order to see whether the newly introduced varieties retain their productiveness in full degree, or whether they fall off, so that the substitution of successive new varieties merely serves to maintain the sugar production at a high level, but does not tend to raise that level to the extent that is hoped and desired. Now that it is the commonly accepted practice on the majority of West Indian sugar estates to weigh the canes which are delivered to the large factories, and seeing that in the factories continuous analyses are made of the juice obtained from these canes, there should be in existence some data whereby it may be possible to learn something definite concerning the stability or otherwise of seedling canes during the years subsequent to their introduction into cultivation on a large scale.

Still the fact remains that the continued production of new seedling canes is a matter of moment for the sugar industry. This work affords means of combating many of the forms of fungus disease to which sugarcanes are liable, and it also affords the means of maintaining the level of production, even if it does not tend to raise that level so rapidly as was at one time hoped might be the case. It is therefore work essential for the well-being and development of the industry, and should be carried on continuously. [J. A. V.]

The Rat: A Plantation Menace.

By Donald S. Bowman.*

Rat extermination has received a great deal of attention on many of the plantations, owing to the great damage rats have done in the cane fields and through spreading the dreaded bubonic plague. There is no excuse for the rat's existence, as he serves no useful purpose in life and is a disease-carrying pest destroying thousands of dollars worth of cane each season. Every effort should be made to exterminate rats of all species. We should be able to recognize the different species and be familiar with their habits, and should have information as to what successful measures have been undertaken by others toward their extermination.

Species in Hawaii.

(*Mus norvegicus*) Norway or grey rat, which is readily identified by the large size, blunt muzzle and small ears and tail, the tail being shorter than the body and head. This rat is a burrower, living largely in gulches, stone walls, and cane fields. On the mainland this rat offers one of the most remarkable instances of successful usurpation to be found in the animal kingdom, it having driven the other species out of existence in many localities. This does not apply in Hawaii, as the black *rattus* and white-bellied *alexandrinus* are still in the majority. This conclusion is reached from a study of the rats caught in traps and may not be entirely correct owing to the fact that the Norway is the hardest rat to trap, he being the most sagacious and the most prolific breeder, having eight to ten young at a litter and breeding from three to six times each year. Its favorite diet is sugar cane, which is destroyed through gnawing. Some meat is required, which, when not easily obtained, leads to cannibalism.

(*Mus rattus*) Black rat; long known in Hawaii as the tree or house rat. It is black in color, smaller than the Norway rat, and of more elegant build. Its slim tail is longer than the body; ears are large; muzzle is long and pointed. It lives in trees, buildings, etc. It is less prolific than the Norway; its diet is about the same.

*Director, Industrial Service Bureau, H.S.P.A.

(*Mus alexandrinus*) Roof rat. In size, shape and habits similar to the black rat. He is lighter in color, with a white belly.

(*Rattus hawaiiensis*) Hawaiian rat. Described in Vol. III, No. 4, Occasional Papers, Bishop Museum. This rat is nearly extinct.

Destructiveness.

Exact figures as to the damage done by rats are not available, but the damage done to the cane fields alone runs into thousands of dollars each year. It is interesting to note that the cane growers of Porto Rico estimate their annual loss at $75,000.00. The estimated loss on the mainland amounts to $180,000,000.00 per year.

Disease Carriers.

Plague-infected rats have been trapped and found dead on the Island of Hawaii since 1900, and the history of the majority of the human cases of plague points to the transmission of the disease by plague-infected rats which were trapped or found dead on the premises where human cases occurred. Plague infection in the great majority of cases is flea-borne from rats to human beings, the fleas feeding on the plague-infected rat and then biting the humans. The India Plague Commission reports that plague is a disease of the rodent primarily and accidentally, and secondarily a disease of man.

Rat Destruction.

All known makes and devices for catching rats have been tried out by the plantations. The best all-around trap so far in use is a snap or dead-fall trap known as the "Official."

In trapping rats much depends on the trapper, as the traps must be properly cared for and placed, using the bait that will be taken. It is important that no other food in kind be available. It must be borne in mind that the kind of bait is of less importance to the rat than the matter of its availability. As a general rule bacon is the best all-around bait.

No poison exists that when eaten will dry up carcasses and prevent putrefaction or that may be relied upon to drive the animals from the premises to die. The brown rat when poisoned seeks its burrow, wherever located. A slow poison will usually allow it to reach this retreat, and thus is less liable than a quick poison to give unpleasant results in dwellings. This statement does not applv to the black rat or the roof rat nor to the common mouse, which are not burrowing species, but which usually live in the walls of houses. This accounts for the small number of dead rats of the Norway species found where poison has been placed in the cane fields and on gulch sides.

For poisoning rats or mice in open fields, at garbage dumps, on river banks, in warehouses, and in similar situations, the following formulas are recommended:

Strychnin (Sulphate) Formula:

Dissolve 1 ounce of strychnin (sulphate) in a pint of boiling water. Dis-

solve a heaping tablespoonful of dry laundry starch in a little cold water, add it to the strychnin solution, and continue to boil for a few minutes until the starch is clear. Add a scant teaspoonful of saccharin or a cup of thick sirup to sweeten the paste and stir thoroughly. Pour this mixture while hot over 12 quarts of clean oats in a metal tub and mix until all the grain is coated. Before using, let the grain stand until the coating dries. Occasional stirring will hasten the drying. Scatter the grain near rat burrows or runs.

Strychnin (Alkaloid) Formula:

Mix thoroughly 1 ounce of powdered strychnin (alkaloid), 1 ounce of common baking soda (bicarbonate), and ⅛ ounce of powdered saccharin. Put the mixture in a tin pepperbox and sift it gradually over 30 pounds of crushed oats in a metal tub, mixing the grain constantly so that the poison will be evenly distributed. Put out the poisoned grain about the rat burrows or runs, but not in piles of more than a teaspoonful.

Barium Carbonate Formula:

Barium carbonate for rats or mice may be fed in a dough paste of 4 parts of meal or flour to 1 part of the mineral. A more convenient bait is ordinary oatmeal (rolled oats) with about ⅛ of its bulk of barium carbonate, mixed with water enough to make a stiff dough. This may be exposed in bulk in a pan, or put out, about a teaspoonful at a place, in rat runs. Eaten in sufficient quantities this mineral is dangerous to all animals, and caution is needed in its use.

While most salts of barium are dangerous, barium sulphate, which is sometimes sold as a substitute for the carbonate, is not poisonous to rats or other animals.

Phosphorus Paste: (The prepared pastes on the market are the most practical and economical, "Stearns'" being the most generally used.)

Spread on stale bread sliced thin. Can be mixed with barley, cheese or other baits. This poison is endorsed by many as the best on the market, although it is expensive to use on a large scale.

A number of biological products have been sold as rat exterminators, including "Danyoz virus," "Ratin," and "Ratite," all of which have been tried out locally and the results of which do not warrant their use.

RAT-PROOFING.

The slogan adopted by the U. S. Public Health Service, "Build the rat out of existence," should appeal to us all, for in this manner only can we keep our habitations free from rats. All dwellings and buildings where food supplies are stored should be made rat-proof. There should ~~be no~~ floors on or near the ground, and no double walls. All concrete foundations and floors should be surrounded by wing walls carried down to a depth of two feet.

A number of plantation villages have been made practically rat-proof through

raising all buildings two feet from the ground and doing away with double walls, etc. This work should be carried on until all settlements, especially in districts where plague is endemic, are made rat-proof, for in this way only will we be able to keep out the rat, thus lessening the danger of plague infection.

The rat-proofing will keep the rats away from the habitations and no doubt will reduce the rodent population in and near the settlements.

Rat Damage Might Be Reduced Nine-tenths.

From the Year Book of the Department of Agriculture for 1917 the following is quoted:

> To combat the rat successfully is largely a building problem. Buildings should be so constructed as to exclude the animals from shelter and food. When this is done, individual and community efforts to destroy rats will give satisfaction and lasting results. The program may be regarded by many as too expensive. Will it be too costly? What do rats cost now? If half the money now spent in feeding and fighting rats could be expended in wisely planned and well-executed cooperative efforts for rat repression, it would be possible within a few years nearly to rid the country of its worst animal pest, to reduce losses from its depredations by at least ninety per cent, and to free the land completely from the fear of bubonic plague.

Rat Eradication.

A report from the Japanese Government on anti-rat measures deprecates the value of trapping and poisoning as an anti-rat measure, contending that with the temporary reduction in rat population by these measures the relatively increased food supply and harborage stimulate breeding and longevity of rat life to a compensatory degree. Many other authorities hold that in thickly populated localities rat destruction is of little value. All, however, agree that rats can to a great extent be built out of existence.

The eradication of rats from our cane fields presents an entirely different problem Here we have to deal largely with the Norway rat, the burrower who lives in or near the cane with an abundance of food. As it is not necessary for him to seek water, the cane juices supplying the needed liquid, living as he does on cane he is easily poisoned by other food baits, and when this occurs he seeks his nest, which accounts for the few found when poison is placed.

Plantations that have used poison to any great extent in the fields report good results, but in the minds of many it is a question of whether the expense involved warrants a field campaign.

In California, where an active anti-ground-squirrel campaign has been conducted for a number of years, splendid results have been achieved. As our field rat problem is the same, it would seem that the eventual results should be the same. It is evident that too much attention has been paid to the number of rats found dead and not enough to checking the lessened damage done to cane where active concentrated poison campaigns have been conducted.

RAT CAMPAIGN.

Where there is any great loss from destruction of cane by rats, it would seem good business to conduct an active concentrated field campaign of poisoning in a given section, checking this section against a like section where no campaign has been carried on. From the writer's experience in conducting extensive rat campaigns he is of the opinion that surprising results in cane saved will be proven. In districts where rat campaigns are conducted as anti-plague methods, the object is two-fold—first, to destroy the rat and drive him away from human habitation; second, to secure enough dead rats through either poisoning or trapping to ascertain by bacteriological tests whether or not plague-infected rats are present, thus keeping tab on the spread of the disease and being able to concentrate on rat destruction where plague-infected rats are found.

The Thomas and Petree Process for Handling Juice Settlings.*

The following is a short description of the method of procedure in working the Process for a treble crushing plant, where the thin juice obtained from the final crushing of the bagasse is returned as a maceration fluid to the first mill bagasse, and after this macerated bagasse has been crushed in the second or intermediate mill, water is applied to the twice crushed bagasse to form the final thin juice previously referred to.

The juice from the second mill (which contains most of the gummy and colloidal impurities expressed in the heavy second and later crushings) is preliminarily defecated and separately settled and decanted.

The resulting clarified second juice joins the first mill juice and this rich mixture is defecated and settled.

The rich mud from the settling of this mixed juice joins the second mill juice prior to it being preliminarily defecated and settled.

The clear juice resulting from the settling of the defecated mixed juice is sent to the evaporators.

A special mud formed from the settling of the second juice plus rich mud is returned to the bagasse at an early stage of the crushing without prejudice to the efficiency of extraction at the mills.

The returning of the rich mud or precipitate into the thin second crushing juice results in the whole of the solid impurities being ultimately withdrawn from the juice in the form of a mud, the liquid content of which is much lower in sugar than that of ordinary defecation mud.

The mixing of the flocculent rich mud or precipitate previously settled and consolidated with the second juice also assists in its clarification by enveloping and entrapping the gummy and colloidal impurities which are mainly found in the thin juices. [R. S. N.]

*From a pamphlet, "Abolish the Filter Press," issued by the General Thomas and Petree Process Co. of Australia.

Alfalfa at the College of Hawaii.

At this time, when many plantations are undertaking the raising of alfalfa as a green forage crop for plantation stock, the work done at the College of Hawaii by Professor L. A. Henke along this line is of interest. From Bulletins 5 and 6 it is learned the Peruvian variety seems to meet the conditions in Hawaii, and gives splendid yields.

The yields of green forage on an acre basis since 1916 for the different varieties are as follows:

Variety.	1916.		1917.		First Half Year, 1918.		July, 1918—June, 1919.	
	Yield in Tons of Green Fodder (Acre Basis).	Number of Crops During Year.	Yield in Tons of Green Fodder (Acre Basis).	Number of Crops During Year.	Yield in Tons of Green Fodder (Acre Basis).	Number of Crops	Yield in Tons of Green Fodder (Acre Basis).	Number of Crops
Peruvian	37.07	8	40.78	9	22.13	4	33.82	9
Kansas	31.59	7	38.98	9	25.36	4	33.04	9
Arabian	47.50	7	38.12	9	27.50	4	45.80	9
Hairy Peruvian..	......	......	38.83	7	29.08	4	57.75	8
Utah	40.50	6	......	......	......	......	......	......
Australian	31.00	7	27.43	8	......	......	......	......

It is figured that the ratio of green forage to that of dry alfalfa hay is one to four, i.e., the above table represents weights that are about four times as large as the amount of dry alfalfa that would result if the green material were cured into hay.

It is pointed out that the cost of establishing a field of alfalfa is often high on weedy and rocky ground, but once established it needs very little further attention, and maintains itself many years. The College farm has several fields of alfalfa that are over three years old, and still producing well, as the above quoted figures show. It is possible to reduce the cost of establishing a new field in weedy ground by repeated discings so as to germinate and kill as many weed seeds as possible before planting the alfalfa. The alfalfa seedlings are very delicate for the first few weeks after coming up, and to hand weed an acre adds to the labor costs. It is planted in rows thirty inches apart, and cultivated and irrigated when necessary. The presence of nut grass in some fields has caused much trouble.

The following costs per ton are given for a yield per acre of Peruvian alfalfa of 54.88 tons green forage in 1916, and 41.95 tons in the same field for 1917:

	1916.	1917.
Man labor	$4.82 per ton	$2.23 per ton
Horse labor	.88	.58
Fertilizer	.33	.44
	$6.03 per ton	$3.25 per ton

The alfalfa is fed as green roughage to cattle and hogs, and in the form of cured hay to the horses. The feeding of green alfalfa in large quantities to working horses is considered too laxative in action, especially when cut before flowering. The same difficulty along this line is experienced to a lesser extent when fed to cattle, but is avoided by mixing with the green alfalfa sudan grass, sorghums, or sweet potato vines. [W. P. A.]

Kudzu.*

By Robert H. Moulton.

There are thousands of people in the cities throughout this country who grow climbing vines over summer house, front porches, pergolas and so forth, for shade or screening. For many years honeysuckles, moon vines, cinnamon vines, virgin's bower, Virginia creeper, or some other plant has been grown. But there is another climbing vine that is becoming very popular, and that is the kudzu plant. This is a perennial plant, and one of the fastest growers known. It makes a beautiful growth, the leaves being a dark green, and produces a dense growth providing a splendid shade. But the kudzu plant has another virtue and one that should place it ahead of any other climber today. That virtue lies in its value as a food for stock. It is richer in protein than alfalfa, and animals thrive on it. Although a perennial, the vines should be cut down to the ground each fall at the approach of winter. The heavy growth of even one vine will sometimes make more than one wagon load of good hay.

This remarkable vine gives promise of being one of the leading sources of wealth in certain sections of the country in the near future, especially in some of the southern states. It really is a pea vine that springs up from the roots when the first warm days come in the spring of the year and grows vigorously until a killing frost comes in the fall. This gives a growing season in some states of at least eight months in the year, during which several cuttings of hay can be made. Instances are known where four cuttings of hay, averaging ten tons per acre in a single season have been made. The hay is of the highest quality, being equal to cow peas or alfalfa and much richer than timothy.

The average analysis made by the state chemist of Florida, where the vine is now quite common, shows protein 17.43 per cent and starch and sugar 30.20 per cent, which makes it a somewhat richer food than wheat bran. Another remarkable feature is that although the hay is as rich a food as alfalfa it is entirely free from the tendency to cause loose bowels and bloat in horses and other livestock which interferes so seriously with the use of alfalfa. When moistened, kudzu becomes almost like fresh foliage again and makes an excellent green ration for poultry in winter. It is well adapted for use in making mixed feed stuffs and for all other purposes for which alfalfa can be used. The hay cures very quickly, retaining its leaves and bright color instead of shedding as cow peas

*The Field, Illustrated, January, 1920.

and velvet beans do; in fair weather only one day is required until it is ready to be put in the barn. For this reason it can be easily cured in the fields in stocks and under duck covers, thereby obviating the expense of building barns. Labor can also be saved by using sweep rakes instead of hauling the hay on wagons, after it has been cut with a mowing machine and raked into furrows with a common horse rake. Kudzu hay is worth from $20 per ton up, making the product of an acre yield $200 or over.

According to a number of authorities, kudzu is of even greater value for grazing purposes than for hay, since it requires no cultivation after the first season and will thrive upon land that is too poor and rough for any other crop. It has been found to do well on all types of soil from pure sand to the stiffest clay, provided the land is sufficiently well drained to admit of growing corn or velvet beans.

One planting of kudzu is permanent and the yield of hay increases as the ground becomes more thickly set with the vines, taking root at the joints. The great number of vines struggling for air and light creates a tendency to make them more slender and leafy, and thus improves the quality of the hay by eliminating any coarse vines, thereby enabling horses and other livestock to eat it up clean without any waste. The vines that run along the surface throw out roots at the joints, and these becoming new plants bind the soil firmly together, thus preventing the washing and erosion of hillsides by heavy rains. While this improvement is taking place the field is giving fine returns to its owner through the immense supply of rich forage on which the cattle, horses, and other livestock can graze. The result is that they are kept fat and in fine health at a very small cost for eight months of the year.

The roots of kudzu penetrate so deeply as to make it proof against any dry weather that is ever likely to prevail in most sections of the country. This feature and its peculiar habit of neither blooming nor bearing seed under field culture causes the vines to remain green and growing during the entire period from spring to fall. The hay can therefore be cut at any time that is convenient, when weather conditions are suitable for curing the hay, as kudzu is not injured by waiting for good weather as other hay crops are. This feature gives it an immense advantage over any other crop.

Kudzu is propagated by means of the plants that have rooted from the joints of the vines and when transplanted carry with them on their roots the tubercules that are needed to inoculate the soil of the new field. In planting kudzu the land should first be deeply plowed, then harrowed, and finally checked into rows 8½ feet apart each way, setting a plant at each check. Tap roots should be laid along the bottom of the furrow, with crowns slanting upward to within two inches of the surface, and then covered with loose earth to the level of the surface. This requires 1,018 plants per acre. One man and a boy can set several acres in a day. The man carries a shovel and opens up the holes by sticking it in the ground and pressing the handle forward, while the boy, carrying the plants, sticks them in back of the shovel. The shovel is removed and the man steps on each side of the plant to press the earth firmly, after it falls back on the plant.

The proper time for planting kudzu is two to three weeks in advance of corn planting, or a little earlier if one can get the ground ready. A full crop of corn

may be grown on the same land, the first year, by dropping the grains between the plants. Neither will interfere with the other and both need about the same attention, only the ground should be left smooth and level at the last cultivation to permit easy rooting of the vines or runners and subsequent mowing for hay. Plants cannot root so well on a rough surface.

After the first year the kudzu will not need any cultivation, as the vines will run all over the ground the second season and take root at the joints, growing so rapidly as to choke out all other plants, even such pests as nut, Johnson, and Bermuda grasses. At the same time it is an easy matter to get rid of kudzu if desired, for the plants will sprout only from the crowns and can be killed by cutting off the crowns with a disc plow in hot, dry weather in summer. For this reason there is no danger of kudzu ever becoming a pest.

Kudzu is perfectly hardy all over the United States and endures the winters as far north as Nova Scotia. It will, therefore, be a valuable crop in the northern states as well as in the south, although the longer growing season in the south is naturally an advantage. [H. P. A.]

The Effect of Concentration on the Deteriorative Activity of Mold Spores in Sugar.*

By NICHOLAS KOPELOFF, S. BYALL, and LILLIAN KOPELOFF.[1]

It is common knowledge that the reduction of the moisture content of sugar is responsible for a diminution of deterioration. This is tantamount to stating that an increase in concentration of the films surrounding the individual particles in any given mass of sugar produces the same effect. The influence of this factor on the activities of bacteria has been the subject of thorough investigation by Owen,[2] and our recent work[3] with molds has led to the conclusion that "the factor of safety for sugars well infected with molds would appear to be lower than is generally supposed." The full import of such a consideration depends to a considerable degree upon the fact that molds may be responsible for the inversion of sucrose where only spores are present as well as when mycelia are developed. Furthermore it has been shown[4] that the invertase activity of mold spores is ex-

*Read at the 58th Meeting of the American Chemical Society, Philadelphia, Pa., September 2 to 6, 1919, and reprinted from The Journal of Industrial and Engineering Chemistry, March, 1920.

[1] Department of Bacteriology, Louisiana Sugar Experiment Station, New Orleans, La.

[2] Owen, Louisiana Bulletin, 162.

[3] Kopeloff and Kopeloff, Louisiana Bulletin, 166 (1919).

[4] Kopeloff and Byall, "The Invertase Activity of Mold Spores as Affected by Concentration and Amount of Inoculum." Read at the 58th Meeting of the American Chemical Society, Philadelphia, Pa., September 2 to 6, 1919, to appear in Jour. Agr. Res., February 15, 1920.

hibited at concentrations of sugar solutions varying from 10 to 70 per cent, with maximum activity at 50 to 60 per cent. In the same connection it was observed that an increase in the number of mold spores is responsible for increased invertase activity at any definite concentration—including saturated solutions. While these might be considered sufficient grounds for inference regarding the deteriorative activity of mold spores in sugars of known composition, it was deemed advisable to carry out such an investigation on a more practical scale.

TABLE I—SUMMARY SHOWING PER CENT INCREASE IN REDUCING SUGARS IN INOCULATED MOLASSES AFTER FOUR MONTHS' INCUBATION

Concentration	Cladosporium	Aspergillus flavus	Aspergillus S. Bain.	Penicillium expans.	Syncephalastrum	Aspergillus niger	Moisture ratio
Blackstrap	......	......	18.4	9.8	......	4.7	0.44
5/6 B. S. + 1/6 sirup ...	5.8	......	19.7	22.3	......	......	0.49
4/6 B. S. + 2/6 sirup ...	38.3	12.3	53.2	56.7	......	36.1	0.57
3/6 B. S. + 3/6 sirup ...	53.8	33.7	83.6	71.6	9.5	73.6	0.63

A series of sugars with films of known composition were made in the laboratory by coating large crystals of sterilized sugar with sterilized blackstrap molasses and 60° Brix sugar sirup in definite proportions, and purging in the centrifugal, a method previously employed with success.[5] These sugars and corresponding molasses were aseptically inoculated with mold spores by adding 15 g. of sugar containing approximately 1000 spores per g. (prepared as previously described)[6] to 135 g. of sugar in tightly corked Erlenmeyer flasks which were paraffined. The molasses was inoculated with a single scoopful of mold. Solid rubber stoppers, paraffined three times at short intervals, were later used. All flasks were incubated at 28° to 30° C.

In Table I is presented the summary of the per cent increase in reducing sugars over check as resulting from the inoculation of molasses by molds, all values representing the averages of closely agreeing triplicate determinations. These data will appear in greater detail in bulletin form.[1] It will be observed that with each mold used the per cent increase in reducing sugars is made greater with a decrease in concentration of the molasses medium at the end of a four-month incubation period. There was a corresponding decrease in sucrose Clerget in every sample. While this increase is striking, it does not follow a rigid mathematical progression, due to certain discrepancies which result from such a method of inoculation. It will be seen from Table I that *Aspergillus* Sydowi Bainier and *Aspergillus niger* exhibit the maximum inversion, closely followed by *Penicillium expansum*. This corroborates previous conclusions concerning the deteriorative activity of these organisms both in the mycelial and spore stage.[2]

Since such definite increases were obtained when molasses of known concen-

[5] Owen, Loc. cit.

[6] Kopeloff and Kopeloff, "Do Mold Spores Contain Enzymes?" Read at the 57th Meeting of the American Chemical Society, Buffalo, N. Y., April 7 to 11, 1919, and printed in J. Agr. Res., [4] 18 (1919), 195.

[1] Kopeloff, "Biological Factors Affecting the Deterioration of Cane Sugar," Louisiana Bulletin (in preparation).

[2] Kopeloff, et al., Loc. cit.

trations were used, it might be expected that refined sugar coated with such different molasses would yield similar results. That this is practically the case may

TABLE II—SUMMARY SHOWING PER CENT INCREASE IN REDUCING SUGARS OF INOCULATED SUGARS AFTER ONE MONTH'S INCUBATION

Concentration	Aspergillus niger	Aspergillus S. Bainier	Penicillium expansum	Moisture ratio
Blackstrap	31.0	142.9	95.2	0.20
4/6 B. S. + 2/6 sirup	75.0	195.0	170.0	0.08
5/6 B. S. + 1/6 sirup	70.4	270.4	170.4	0.14
3/6 B. S. + 3/6 sirup	95.7	391.1	239.1	0.18
3/6 B. S. + 3/6 sirup	104.6	404.5	218.2	0.20

be judged from the data in Table II, which represents a summary of the per cent increase in reducing sugars over check as resulting from an inoculation with mold spores at the rate of 100,000 per g. after one month's incubation. It will be seen that an increase in moisture ratio

$$\text{M. R.} = \frac{\text{Moisture}}{100\text{—Polarization}}$$

which means a decrease in concentration, is responsible for raising the per cent increase in reducing sugars in most instances, except where blackstrap films were employed. The latter phenomenon may be accounted for by the fact that the molasses film was relatively thin, due to too prolonged purging. However, the other data, despite negligible discrepancies, are substantial proof of the direct effect of concentration on the deteriorative activity of molds. This has been proven to be a case of true inversion by the fact that an increase in reducing sugars has almost invariably been accompanied by a decrease in sucrose Clerget in the same sample. As in all previous work, *Aspergillus* Sydowi Bainier exhibits the greatest power of inversion.

If the results in Table II are compared with those presented in Table I, it may be noted that there was a greater deteriorative activity revealed in the former case where the moisture ratio was actually much lower. This would seem, upon the surface, to contradict the conclusion that a lowering of the concentration of the medium increases the deteriorative activities of molds. However, it must be remembered that the deteriorative activity of molds in any single medium is a resultant of at least two variables, *i. e.*, concentration and amount of inoculum. We have shown in another paper[1] that an increase in amount of inoculum is responsible for an increase in inversion in any sugar solution of definite concentration. That this principle applies to manufactured sugars is indicated here, for the inoculum used in Table II was approximately 100 times as large as that employed in Table I. Consequently, this experiment shows that a decrease in concentration causes increased deteriorative activity in mold-infected sugars, all other things being equal. Nevertheless, the effect of other variables cannot be overlooked. A similar experiment was repeated over a period of four months and the data gave similar evidence with moisture ratios varying from 0.18 to 0.29.

[1] Kopeloff and Byall, Loc. cit.

Considering the importance of the moisture ratio in predicting the keeping quality of sugar in storage under what is known as the "factor of safety" rule, it is of special interest to note that here is presented evidence of the deterioration of manufactured cane sugars with moisture ratios from 0.08 to 0.29 when sufficiently infected with mold spores; and, furthermore, that this deterioration occurs even in films of the highest concentrations, namely, of blackstrap molasses. In sugar solutions we have already arrived at the resultant effect of the combined variables of concentration and amount of inoculum. In other words, in saturated sugar solutions upwards of 5000 spores per g. are required to effect inversion.[1] We have experiments nearing completion which should establish similar criteria for sugar coated with films of known concentration as herein described. In this way it is our purpose to arrive at a satisfactory method of judging the keeping quality of a sugar from the standpoint of mold infection, which we have shown to be capable of inducing serious economic losses in sugar as a result of its deteriorative activity.

We wish to acknowledge our indebtedness to the Station staff for their kind assistance.

SUMMARY.

1—A decrease in concentration of molasses inoculated with molds is responsible for a progressive increase in reducing sugars and a decrease in sucrose Clerget when incubated at 30° C. for four months.

2—A decrease in the concentration of films in inoculated laboratory-made sugars having films of known concentration and moisture ratios of 0.08 to 0.20, caused an increase in reducing sugars (and a decrease in sucrose Clerget) which gave evidence of active deterioration. These sugars were incubated at 30° C. for one month, and similar results followed a like incubation of four months.

3—*Aspergillus* Sydowi Bainier, followed by *Aspergillus niger*, and *Penicillium expansum,* in the order named, effected the greatest deterioration in both molasses and sugar.

4—There is evidence that an increase in inoculum is responsible for an increase in inversion at definite concentration. This investigation with laboratory-made sugars corroborates previous results obtained with sugar solutions.

[W. R. M.]

[1] Kopeloff and Byall, Loc. cit.

Potassium Nitrate From the Chilean Nitrate Industry.*

By P. F. HOLSTEIN.†

Most of the information published regarding the possibilities of the production of potash in the Chilean Nitrate "Oficinas" and the present status of the question has been entirely general in character and at times misleading. The importance of this source of supply has been appreciated indeed by only very few of the nitrate producers themselves, yet during the war and at the present time several Oficinas (not more than half a dozen in all) manufactured a grade of nitrate containing a high percentage of potassium nitrate. Oficina Delaware of the du Pont Nitrate Company, a subsidiary of E. I. du Pont de Nemours and Company, has been the pioneer in this new development, which bids fair to be a factor of considerable value both to the nitrate producer and the potash consumer. The industry at the present time seems to be in rather a receptive mood as regards development of new methods, as is evidenced by numerous experimental plants, and it is very probable that the next few years will see the production of potassium nitrate in increasing quantities from the pampas of Chile. This article aims to present some of the main facts of the situation and to describe briefly the means actually at hand by which potash may be recovered.

During the year ending June 30, 1918, there were produced in Chile 64,340,267 quintals of nitrate (one quintal = 101.4 lbs.), or over six and a half billion pounds. The average potassium nitrate content of all the nitrate shipped is probably about 2 per cent, so that there were contained in this nitrate about 130,000,000 lbs. of potassium nitrate for which the producer received no additional profit. Calculated on a basis of K_2O this represents 30,000 tons of potash or about 21 per cent of the total consumption of the United States.

That this potash may be separated successfully and sold as a distinct product there is not the least doubt. This has been done since 1914 by a number of Oficinas and there are probably 100 more in the country that could do the same. Even if the price of potash should drop to the pre-war level there would still remain a substantial profit to the nitrate manufacturers, a fact of importance in meeting competition from artificial nitrate in years to come. The additional equipment necessary requires but a comparatively small outlay and should, in addition to the recovery of potash, have a definitely beneficial result on the percentage extraction of the ordinary nitrate. Moreover, this development occurs in an industry already established and accustomed to the handling and treatment of solutions on a large scale.

For many purposes there is a great advantage in the fact that this potash is in the form of nitrate, not chloride or sulfate. In this respect it differs from the potash from all other sources except the "East India Crude" product. It may

*The Journal of Industrial and Engineering Chemistry, March, 1920.
†Assistant Administrator, Oficina Delaware, du Pont Nitrate Company, Taltal, Chile.

be refined readily to pure potassium nitrate, or used in fertilizers. The latter is a larger and more likely field. The product as turned out by the Oficinas would be a mixture of sodium and potassium nitrates containing from 20 per cent to 80 per cent of the latter salt.

The grade manufactured by any single plant depends primarily on the percentage of potash in the "caliche" or crude nitrate ore. An Oficina having 2 per cent to 3 per cent potassium nitrate in its caliche may easily recover potash in good quantity. The caliche of a majority of Oficinas will contain this amount and there are many having ore up to 5 per cent or even 7 per cent potassium nitrate. Those having a high percentage of potash in their ore have, of course, a great advantage both as to grade of product and as to cost of production. In fact, an Oficina having 5 per cent potassium nitrate in the ore may produce a certain amount of a marketable product high in potash at only a negligible cost above that of its regular sodium nitrate.

With ore of 3 per cent potassium nitrate a grade of high potash nitrate containing 25 per cent, 40 per cent, or 60 per cent may be made, depending upon the method of manufacture. An Oficina with a production of 50,000 quintals per month and an ore averaging 3 per cent potassium nitrate may divide this total production into approximately 40,000 quintals of ordinary nitrate and 10,000 quintals of "high potash" nitrate containing 25 per cent potassium nitrate, or 43,750 ordinary nitrate and 6,250 high potash nitrate containing 40 per cent potassium nitrate, etc. The production of this extra grade of nitrate will not as a rule add to the sum total in quintals of the "make" of the Oficina, but merely convert part of it into a more valuable product than ordinary Chilean nitrate.

The high potash nitrate is separated from the mother liquor resulting from the treatment of the caliche. The composition of the hot concentrated liquor that is run from the boiling tanks to the crystallizing pans varies with each plant, and from day to day at the same plant, depending upon the class of material being extracted. The two following analyses are more or less typical of Oficina Delaware, representing liquors obtained from caliches of between 2 per cent and 3 per cent of potash calculated as potassium nitrate.

	Hot Liquor	Mother Liquor
	(G. per 100 G. Water)	
Total Salts	146.61	90.99
Sodium Nitrate	100.04	40.95
Potassium Nitrate	20.87	19.96
Sodium Chloride	19.02	22.17
Specific Gravity	1.5050	1.4225
Temperature ° C	74	9.5

There are many other salts in solution, such as sulfates, borates, iodates, perchlorates, magnesium, calcium, etc. The analyses given, however, are sufficient for this discussion.

The hot crystallizing liquor stands from five to ten days in the crystallizing pans during which time there is considerable air evaporation. This accounts for the fact that the weight of sodium chloride per 100 g. water has increased. For the same reason it will be evident that a small amount of potassium nitrate has deposited along with the sodium nitrate.

The important point is that the mother liquor is saturated at air temperature with potassium nitrate in a solution of many other salts. Very often the solution is saturated with potassium nitrate at temperatures much above that of the air, in fact as high in some Oficinas as 40° C. Under these conditions there will be deposited along with the sodium nitrate, on cooling, from 1 per cent to 10 per cent of potassium nitrate, and even more in a few plants exceptionally fortunate in the potash content of their ores. As the mother liquor is used over and over again in the extraction of fresh lots of ore it takes up more potash, depositing it in turn in the nitrate, except in cases where the potash is recovered and removed from the mother liquor before returning it to the plant. Referring to the above analyses it will be seen that if the hot liquor had contained 35 g. of potassium nitrate per 100 g. of water there would have been deposited about 15 g. when the liquor had cooled. As about 60 g. of sodium nitrate deposited, and the final product after deducting moisture, salt, insoluble matter, and sulfate is about 95 per cent nitrates, it is clear that the deposit would have contained about 19 per cent potassium nitrate. If the hot liquor had contained 25 g. potassium nitrate per 100 g. of water the deposit would have contained something over 7 per cent potassium nitrate.

This is exactly what occurs in the majority of Oficinas. The mother liquor, being used repeatedly through the boiling tanks for the extraction of fresh caliche, becomes rich in potash. The hot liquor as run to the crystallizing pans will not be saturated with potash, but on cooling will be saturated with this salt at a temperature above that of the final temperature to which the liquor cools. Hence the 1 per cent to 10 per cent of potassium nitrate contained in the product shipped from the Oficinas and sold as Chilean nitrate.

Fractional Crystallization—This suggests the first, simplest and cheapest means by which a nitrate containing a high percentage of potassium nitrate may be manufactured, available on any considerable scale, however, only for those Oficinas having a fairly high percentage of potash in their ores, close to 5 per cent calculated as potassium nitrate. Fractional crystallization will then give a commercially profitable high potash nitrate at an insignificant cost above that of their regular nitrate. The liquor when it has reached the proper temperature in the crystallizing pans is merely transferred to other pans where it cools to air temperature, this second deposit being the high potash nitrate. This method does not recover much of the potash in the ore, but does have the advantage of extreme cheapness and ease of operation and might be used immediately by a number of Oficinas which hesitate to install an expensive system. As long ago as 1912, Oficina Delaware recovered a small quantity of high potash nitrate regularly by this method, and one other company at least, to the writer's knowledge, recovered a certain amount by separating the crystals on top in the crystallizing pans. During the war several plants in Tarapacá produced high potash nitrate by fractional crystallization and are continuing to do so. There are undoubtedly many Oficinas which could make a certain quantity of high potash nitrate by this means, but are deterred, either by ignorance of the facts or by lack of a technical staff.

The fact that the mother liquor is saturated with respect to potassium nitrate, or at least contains a fair amount, gives two other methods by which it may be recovered, *i. e.*, evaporation or refrigeration.

Evaporation—By evaporation of the mother liquor there will result a solution concentrated in nitrate, and more or less of the character of the hot crystallizing liquor which is run from the boiling tanks, with the difference that the concentration of potassium nitrate is greater. As the solubility of sodium chloride in a nitrate solution is somewhat less at higher temperatures than in a cold solution, this salt is deposited during the evaporation. There is also, of course, a concentration of various impurities, magnesium salts, boric acid, iodates, etc. Fig. 1 gives cooling curves for a solution prepared by the evaporation of mother liquor. It will be observed that some boric acid is deposited, the nitrate manufactured by this method usually containing about 3 per cent. In operating practice it is usually better to return the mother liquor resulting from the evaporated liquor to the boiling tanks instead of mixing it with the regular mother liquor for evaporation. The liquors are thus "cleaned" of impurities by passing through the boiling tanks over fresh ore. It is also wise to regulate carefully the time of standing in the crystallizing pans, as otherwise the nitrate will be rather high in sulfate and magnesium, and, therefore, in moisture. Little difficulty will be en-

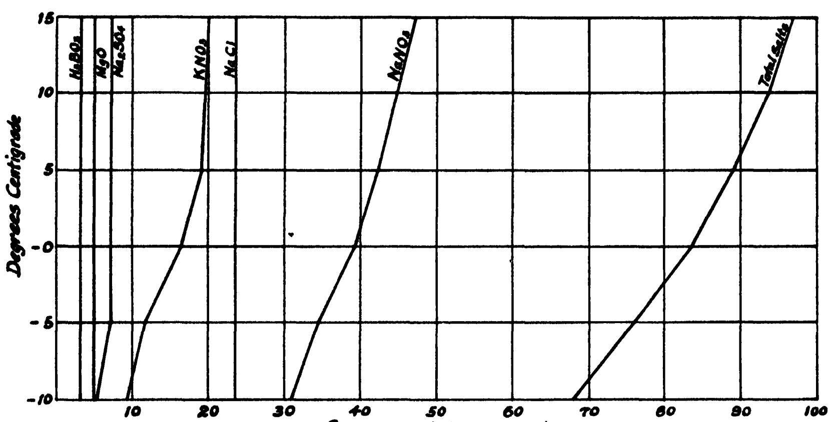


Fig. 1

countered, however, in producing a product containing 93 per cent to 95 per cent total nitrates, depending, of course, upon the potash content of the mother liquor evaporated. Oficina Delaware regularly produced a product by this method containing from 25 per cent to 30 per cent potassium nitrate, and several other Oficinas, having more potash in their ore, a higher grade.

It will be evident from the cooling curves that an evaporated liquor may be fractionated to give a fraction high in potash and a fraction relatively low. There is more or less difficulty in reducing the potash content of the first fraction low enough to avoid a large loss of potash, and unless there is an additional premium for the higher grade material that thus may be separated it is not advisable.

Refrigeration—The third method for the manufacture of high potash nitrate, *i. e.*, refrigeration of the mother liquor, has been in operation in Oficina Delaware since November, 1918, having superseded evaporation. This process is based upon the fact that the mother liquor is saturated with potassium nitrate at air temperature and that at lower temperature the solubility of potassium nitrate decreases more rapidly than the solubility of sodium nitrate. For instance, at 20° C. in the mother liquor there are approximately 55 g. of sodium nitrate and 25

g. of potassium nitrate per 100 g. water; at a temperature of —10° C. there are approximately 35 g. of sodium nitrate and 10 g. of potassium nitrate per 100 g. water, or in cooling through this range of temperature something over one-third of the sodium nitrate is deposited and nearly two-thirds of the potassium nitrate. In this particular instance 20 g. of sodium nitrate would be deposited and 15 g. of potassium nitrate. Assuming the product to be 95 per cent nitrates, the mixture would contain 40 per cent potassium nitrate. The mother liquor which gives a 25 to 30 per cent product by evaporation without fractional crystallization will give by refrigeration a product containing 40 per cent potassium nitrate.

Fig. 2 gives cooling curves for a certain mother liquor from 14° C. to —10° C. One of the main points to be observed is that no boric acid, magnesium salts, or chloride is deposited, and that sulfate did not precipitate until temperatures under —5° C. are reached. This is found to be true in practice, giving a much purer product than is obtained by evaporation. Below are given typical analyses of nitrate made by the two processes:

	High Potash Nitrate Manufactured by Evaporation Per cent	High Potash Nitrate Manufactured by Refrigeration Per cent
Moisture	3.72	0.79
Insoluble	0.10	0.09
$NaCl$	0.76	0.56
Na_2SO_4	0.44	0.35
Nitrate (by difference)	94.98	98.21
CaO	0.16	0.04
MgO	0.44	0.20
$KClO_4$	0.55	0.30
H_3BO_3	3.00	0.17
KNO_3	28.07	42.00

The greatest difference in the impurities is that of the boric acid, a fact that is of importance if the nitrate is to be refined for the manufacture of pure potassium nitrate.

By the addition of a small quantity of water to the mother liquor before refrigeration a nitrate very much higher in potash (60 to 85 per cent) can be produced in a single operation. This involves a great economy in case the nitrate is subsequently to be refined.

Exactly the same recovery of the potash, between 30 and 60 per cent, in the ore will be obtained by either evaporation or refrigeration. It is not entirely clear why more of the potash in the ore does not pass into solution, but the probabilities are that it is because it occurs in the caliche in the form of sulfate or difficultly soluble double sulfates or double salts. Some work has been done upon this subject with the hope of increasing the recovery and it is not improbable that a recovery may be obtained as good as that upon the total nitrate. The ordinary Oficina throws away daily in the tailings about 25,000 lbs. of potassium nitrate. Its recovery commercially is not, however, as simple as would appear at first thought.

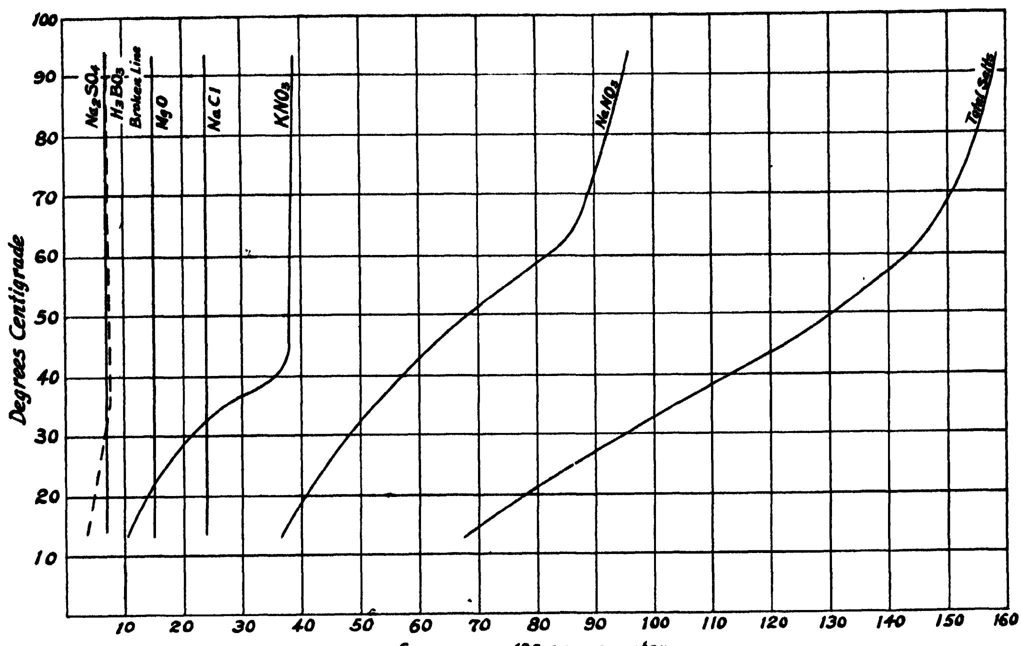


Fig. 2

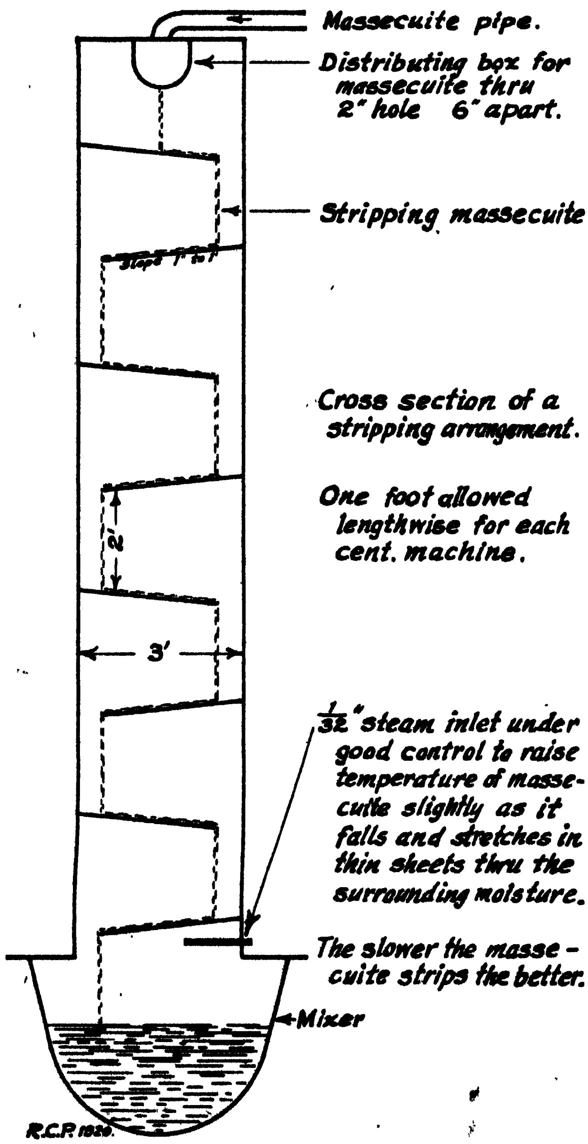
Whichever method for the recovery of potash an Oficina may choose, fractional crystallization, evaporation, or refrigeration, will depend a great deal upon their present plant installation and method of operation, and the conditions peculiar to their own particular plant. The character of the ore and its potash content, the air temperature in summer and winter, the composition of the mother liquor, and numerous other factors must all be given consideration. Refrigeration will produce a higher grade nitrate at a much lower cost than will evaporation. On the other hand, evaporation, if properly carried out in the right type of evaporator, has the advantage that the water removed from the system may be used as additional wash water for washing the tailings in the boiling tanks, thus increasing the recovery of sodium nitrate. The usual type of evaporator will not be found satisfactory because of the heavy precipitation of salts during evaporation. The tubes must be cleaned by washing and if the design of the evaporator makes necessary a large quantity of water for this purpose, considerable of the advantage that otherwise would be gained by driving off water from the system will be lost. Each Oficina should have its own solution as to which method will give the cheapest cost and the best results.

In the above brief discussion only those methods have been mentioned which have been tried on an actual operating scale. There are a number of other possible means, but the ones described are those which at the present time are giving satisfactory results in the few Oficinas that so far have appreciated the opportunity that they have for the manufacture of a valuable by-product. A number of the larger companies are giving serious study and consideration to this new development of the nitrate industry and a year undoubtedly will see a number of other Oficinas producing potash. [W. R. M.]

A Mechanical Aid to Centrifugaling Sugar.*

By R. C. Pitcairn.†

From some remarks made to me by Mr. W. R. McAllep, of the H.S.P.A., on the possibility and desirability of being able to change the viscosity of low grade massecuites of 98 to 99 density to a number of preparatory treatments before centrifugaling same (such as vibration, passing it between rollers, stretch-



Cross section, showing 8 strippings inclosed in 1" board housing, massecuite flowing over board strippers.

*Presented at a special meeting of the Hawaiian Chemists' Association, April 16, 1920.
†Chemist, Wailuku Sugar Company.

ing, passing it through a ¼″ mesh screen, and running it over a system of stripping boards), the best results were obtained by the stripping system, as I shall call it, although this could be modified and the same results obtained a number of other ways. This stripping process is exceedingly simple and consists of allowing the massecuite to flow by its own weight over a number of boards or plate baffles, set approximately 2 feet apart, one above the other, and stretching by its own weight into thin sheets of massecuite. I found that the oftener this was repeated the easier the massecuite purged, and so marked was this improvement that I am trying it now on a larger scale at Wailuku with beneficial results.

The stripped massecuite will give the same purity to the resultant sugar in the basket as the unstripped, in 25 to 35% less time, or in the same length of time it will show a decided increase in purity over the unstripped massecuite. The molasses comes off much faster in the earlier stages of centrifugaling on the stripped massecuite, provided the massecuite is kept warm during the stripping process. In other words, I am able to do in 40 to 45 minutes with the stripped massecuite what it would take an hour to an hour and a quarter with the unstripped, and I get only a slight raise, if any, in the purity on the resultant molasses. The above results I was able to substantiate by weighing the massecuite and the sugar left in the basket. On a high grade massecuite the improvement on the stripped over the unstripped is also marked.

The following figures will give a good idea of the benefits derived from this process:

NO. 2 MASSECUITE—BRIX 95.48, PURITY 46.92

	Time Spun	Temperature	Purity Sugar	Wt. Grms. Sugar	Wt. Grms. Massecuite	Purity Molasses	% Sugar on Massecuite	% Mol. on Massecuite
Massecuite direct from tank to centrifugal machine.	1 hr.	28° C.	66.45	781.5	1678	28.0	46.5	53.4
Massecuite stripped eight times	1 hr.	29° C.	75.83	555.5	1650	29.0	33.7	66.3
Massecuite stripped eight times	40 m.	29° C.	64.10	837.5	1678	27.9	49.9	50.1

The above results were a fair average of six tests made on an 8″ tightly sealed centrifugal machine, running 1,300 R.P.M., screen 00, and showed over 25% improvement.

Massecuite unstripped, spun 1 hr. 10 min. Temp. 29° C.

Massecuite	**Brix** 96.25	Purity 55.60
Molasses	" 92.55	" 33.50
Sugar	" 99.30	" 82.60

Massecuite stripped, spun 50 min. Temp. 29° C.

Massecuite	**Brix** 96.05	Purity 55.20
Molasses	" 94.65	" 33.80
Sugar	" 99.85	" 82.60

Massecuite stripped, spun 50 min. (steamed while stripping).
Temp. 35° C.

Massecuite	Brix 95.75	Purity 54.80
Molasses	" 94.05	" 33.50
Sugar	" 98.15	" 83.00

These results were obtained in the same centrifugal machine as above, except the speed of the centrifugal machine was 1,700 R.P.M., and show practically the same results in 25 to 30% less time. These latter stripped samples were run over the 8-board stripping apparatus in use at Wailuku, as were also the following samples, although these were obtained in a 30" machine, running 1,050 R.P.M. on a very poor quality massecuite.

Brix 93.25 Purity 47.7

212 lbs. unstripped massecuite, spun 1 hr. 30 min. There were 116 lbs. sugar left in the machine, or 54.73%, and 45.27% molasses.

198 lbs. stripped massecuite, spun 1 hr. 8 mins. There were 100 lbs. sugar left in the machine, or 50.51%, and 49.49% molasses—or practically 4% better in 25% less time.

The molasses in both these latter tests was practically the same. In a 98 density massecuite, the improvement varied from 25 to 35%, although I have noticed that the quicker the massecuite is purged after stripping, the better the result.

Regarding the changes that occur to the massecuite due to the stripping process, the Brix was invariably lower after stripping, as was shown by moisture determination, with the spindle and in refractometer tests. The stripped massecuite also runs faster than the unstripped when placed at the same degree of inclination, and appears to have absorbed water, as Dr. R. S. Norris points out, due, probably, to the hydroscopic character of the material.

Also these facts were noticed: the massecuite was invariably warmer after stripping, and had taken up a great deal of air, which characteristic, contrary to the opinion of many sugar men, did not retard its purging.

Regarding the viscosity of the massecuite itself, on tests made through a 2" pipe from a box, before and after stripping, if the stripped massecuite was warmed by the stripping, even slightly, the viscosity was improved, but if it was cooled while stripping, the viscosity was greater, one degree of temperature affecting it a great deal.

I found also that by letting dry steam circulate around the stripping massecuite, the improvement in its purging qualities was still further increased, but that the steam had to be well regulated, and there was danger of too much heat and too much condensate raising the purity of the resultant molasses; 37° C. seems, from my experiments, to be the danger point in heating the massecuite.

This is, I believe, a simple mechanical method of applying heat cheaply, evenly, and in a limited quantity, to a massecuite before purging, and, I hope, that we have a possibility here of a preparatory treatment of the massecuite by a cheap mechanical device that will save fuel and money by reducing the time of centrifugaling, and will increase the present capacity of our low grade machines, give us a better control of the handling of the massecuite, and a higher remelt product. I believe it is well worth your consideration.

THE HAWAIIAN PLANTERS' RECORD

Volume XXII. JUNE, 1920 Number 6

A monthly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

Insecticide Sprays: Their Relation to the Control of Leafhoppers by Parasites.

By C. E. PEMBERTON.

In connection with the present insecticide operations against the cane leafhopper at Olaa Plantation, doubt has been expressed by some as to the advisability of killing the parasites of the hopper in such work. In applying a contact spray to kill the hopper, not only is it destroyed, but parasites, spiders, moths, plant-lice, and in fact a large variety of insects succumb also. Without a complete knowledge of the situation, it is quite natural for one to have fears for the ultimate outcome of such a procedure, when some parasites are actually being destroyed and when it is known that the parasite *Paranagrus optabilis* is our greatest asset on all plantations, in keeping the leafhopper in check.

This particular phase of the subject has been given very careful attention, and the following statement of facts, bearing on the life-cycle and habits of both hopper and parasite and the comparative vulnerability of each to the spray, may serve to allay the fears of any one who will give such facts their thoughtful consideration. It shows that the application of the insecticide is rather of great assistance to the parasites than a check, and very quickly enables them to gain the advantage in the balance of power between the hopper and parasite.

During the winter and spring months of 1920, at Mountain View, it was found that it required about 35 days for the hopper egg to hatch, 62 days for the young hopper to develop to an adult, at least 15 days more before the adult began laying eggs, and that the adult continued laying for at least 20 days. These are averages. There were considerable variations for each. It was found that the parasite completed its entire development, within the hopper egg, in about 42 days, then hatched out and began laying eggs into the hopper eggs immediately, and laid all of its eggs and died in about 5 days more. These figures are taken from a large number of individual records on each stage of development of both hopper and parasite.

From the above figures alone it can readily be seen how much more vulnerable the hopper is to sprays than the parasite. The hopper spends an average of 97 days, out of its total life of 132 days, as an active individual outside of the egg, running about over the surface of the cane leaves. It is in the egg stage, inside of the cane leaf, for 35 days and an active hopper 97 days. The parasite, however, is out of the hopper egg, and exposed to outside influences, for only 5 days of the total period of its existence of 47 days. It is an active parasite 5 days, and a concealed, sealed-up, developing parasite 42 days. Thus about 73 per cent of the hopper's lifetime is spent out on the surface of the cane, while only about 10 per cent of the parasite's life is lived in such exposure. Hence at any one time during a season of spraying, the chances of a ratio of more parasites than hoppers being destroyed, are exceedingly small. It is almost inevitable, under the circumstances of life habit of the two insects, that the parasites will be greatly assisted, even though some of their forces be lost. A much greater proportion of all hoppers present will be destroyed than parasites and a change in balance is quickly effected. This is not a hypothetical case. It is not assumed without proof. These facts alone, if rightly examined, should be sufficient.

As soon as the parasite hatches out it begins ovipositing; that is, it begins laying its eggs in leafhopper eggs. A leafhopper, however, does not begin laying until about 77 days after hatching out. This means that vastly more parasites, that may have been killed by the spray, have already laid from one-fifth to five-fifths of all the eggs they could ever have laid, than hoppers which may have been killed. Almost every parasite will have already laid some eggs, while a large number of hoppers, usually a majority, will either have not yet deposited any eggs, are still immature, or have laid only a few eggs. This all points in favor of the parasite in relation to the spray work.

By way of repetition, it must not be thought that the killing of all parasites on the cane leaves, in the operation of killing the hopper, exterminates the parasites from the field. It must always be remembered that vastly more parasites are always present and developing in the hopper eggs, safely sealed in the cane leaves, than outside, flying or running about.

If it were possible to kill every living parasite and hopper present on the leaf surfaces in an infested area of cane, there would be no more hoppers laying eggs in this area for at least 77 days, assuming that some young hoppers commenced hatching out the following day after spraying. It would be 77 days before they would be old enough to lay (using the above figures for the Mountain View conditions). However, parasites would continue hatching out of the leaves immediately after the spraying, and begin attacking all remaining unparasitized hopper eggs, and continue so hatching out and attacking hopper eggs to some extent during at least the following 35 days, or until all hopper eggs had been parasitized or had hatched. It would mean that hopper eggs would not be laid for 77 days, but parasites would continue laying from 30 to 35 days more. One is going ahead and the other is standing still. It thus gives the parasite a very great ascendency, and a sudden one, by stopping the egg-laying of the hopper, but not checking that of the parasite. All parasites that hatch out tomorrow will be actively laying tomorrow, and so on for a month,

while all hoppers which hatch tomorrow, and the days following, must wait 77 days before old enough to lay. A second spraying, then, before 77 days have elapsed is still more effective. The determination of the fact that the parasite attacks and successfully develops on hopper eggs even when they are old and ready to hatch adds weight to our present argument.

The danger of totally exterminating the parasite in the cane, by totally eliminating the hopper, is negligible. The total eradication of the hopper would, of course, leave no food for the parasite, and it would soon disappear. Even this would be desirable, but it can never be accomplished. The efficiency of the average laborer in applying the spray will always be so low that many hoppers will not be killed. A certain percentage will be unavoidably missed. The remaining few will always leave sufficient eggs in the cane, at any one time, to supply food for the development and perpetuation of the parasites in all fields. no matter how isolated from others.

In practice, as a matter of fact, no detrimental effect of the spray upon the parasite has arisen. The parasitism in the sprayed fields has increased from a very low point after the spraying commenced, to a much higher percentage at present, only a short period later. This increase would have occurred naturally, in considering the cycle of hopper and parasite during the spring months, even without spraying, but it is felt with certainty that it could not have been so rapid, had it not been for the spraying. There has been absolutely no visible interference with parasite activities by sprays, and the coincident increase in parasitism has been surprisingly rapid, and wholly in keeping with the predictions originally drawn from the figures and facts above cited. In the sprayed fields, during March and April, the parasitism ranged from 20 to 30 per cent. On May 9th, the date of the last observation, an examination was made of over 4,000 hopper eggs, taken in several sections of the same areas. The parasitism had then jumped to 69 per cent. These facts should be sufficient to show that no alarming check is given the parasites, by spraying to kill the hoppers, and that actually it assists rather than retards their general effectiveness. It is further significant to know that a decided response in the growth of the cane has accompanied this increase in parasitism, and the decrease of a host of hoppers through the action of the sprays and the use of hopper catchers operated over the entire affected area at the same time.

The Kapok or Silk-Cotton Tree.

Ceiba pentandra (L.) Gaertner.

By H. L. Lyon.

On the cover of this issue we reproduce a picture of a large silk-cotton tree which stands beside one of the main thoroughfares of Jamaica, only a short distance from Kingston. The tree is in itself a very fine specimen of the species, and quite worthy of respect, but it is venerated in Jamaica, for it is the identical

tree mentioned in that famous record of pirate days, "Tom Kringle's Log," and as a result it is popularly known and treasured as Tom Kringle's Tree.

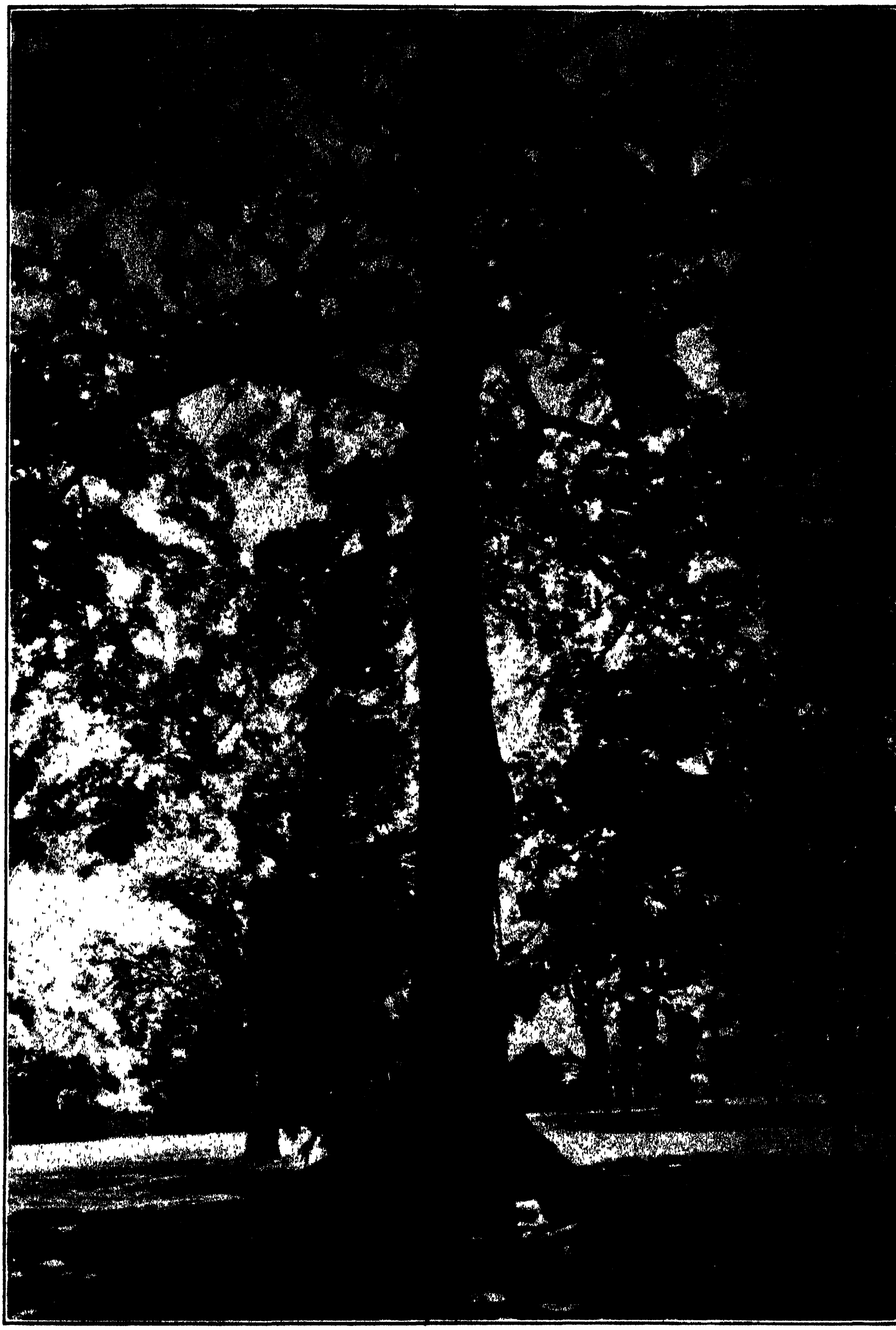
As can be readily seen from the photograph, the main axis of this particular specimen is a short cone supported on all sides by massive buttresses, which suggest enormous strength and stability. The greatest distance through the trunk and its buttresses at the surface of the ground is somewhat over forty feet. At a comparatively short distance above ground the trunk divides up into numerous huge branches, many of which are nearly or quite horizontal, and extend out fifty feet and more from the trunk. These branches carry a veritable garden of perching plants, among which are several species of orchids, numerous pineapple-like Tillandsias and a night-blooming Cereus.

Tom Kringle's Tree represents the form taken by a silk-cotton tree when it is not closely surrounded by other trees, and can push out its branches without interference at a comparatively short distance above the ground. As a component of a forest, however, it is usually a very tall tree, and spreads its lowermost, permanent branches at a considerable distance above the earth. Such specimens are even more imposing than Tom Kringle's Tree, for when in full leaf they present a broad, dense crown borne at a great height on a huge columnar trunk.

Tom Kringle's Tree. The bole is reenforced on all sides by far-flung buttresses.

In Cuba we saw many specimens with immense trunks on which the first branches were fifty to seventy feet from the ground. These trees now stand in cane fields and pastures, but they undoubtedly grew to maturity as components of a forest, and the proximity of other trees caused them to push their crowns to an unusual height in order to monopolize the light.

The silk-cotton tree is native to the tropics of both hemispheres. It is known as "Seiba" in Cuba, and "Kapok" in Java. It is a quick-growing tree of the lowlands. The wood is soft and of little value as timber or fuel, but the trunks



A silk-cotton tree growing in the grounds of the Territorial Nursery on King Street. Note the horizontal position of the branches. This is one of the striking characteristics of the silk-cotton tree.

are used by some peoples in making dug-out canoes. The bark yields a medicinal gum and an inferior fiber.

In the orient, particularly in Java, Ceylon, and the Philippines, the floss, or "silk-cotton," which surrounds the seeds is an article of commerce under the Javanese name *Kapok*. It is used chiefly for upholstering; stuffing pillows, mattresses and the like. It has also been extensively used as a filler for life-belts, buoys, etc. The fiber is too short, smooth and light to be used for textile purposes. In 1912 the oriental countries marketed some 9,000 tons of kapok, of which 8,000 tons were produced in Java. The market price averaged somewhat over $200 per ton.

"The seeds yield 28 per cent of an oil that much resembles cotton-seed oil, and the cake is found to be a highly beneficial cattle food. The oil is used in Holland as food and in the manufacture of soap. It dries more rapidly than cotton-seed oil."[1]

The silk-cotton tree is easily propagated by seeds or cuttings, and thrives from sea level up to 2,000 feet elevation. It is extensively planted along roadsides and in hedgerows in Java, where the kapok is most valued. In the West Indies the tree is not planted to any extent, as there seems to be no interest in the floss as a commercial product.

There are many silk-cotton trees now growing in and about Honolulu. A handsome specimen may be seen in front of the Capitol building on the Ewa side of the drive, while a smaller tree stands on the Waikiki side. Two fine large trees are flourishing in Mrs. Foster's grounds on Nuuanu avenue, and two big trees may be seen on the Waikiki side of upper Nuuanu a short distance below the Queen Emma home. The subject of our photograph on the preceding page stands in the Territorial Nursery on King street, near the Ewa end of the grounds.

A silk-cotton tree may be recognized:

By the straight main axis which usually tapers off rapidly above the first branches;

By the strikingly wide angles at which its branches leave the main axis, many of these being, as a rule, quite horizontal;

By the large conical spines which occur on the trunks of young trees, and on the newer portions of the branches of old trees, but which drop off as the members grow old;

By its palmately compound leaves with five to nine narrow, pointed, stalked leaflets arranged in a whorl at the end of a long petiole;

By its large shuttle-shaped capsules, four to eight inches long, which are closely packed with a copious floss surrounding the seeds;

By its deciduous habit, for it drops all of its foliage and remains bare for a short period each year.

While conspicuous buttresses at the base of the trunk are characteristic of silk-cotton trees, still specimens are occasionally met with which show these only slightly developed or altogether lacking.

[1] The Commercial Products of India, by Sir George Watt.

The Fern Weevil Menace.*

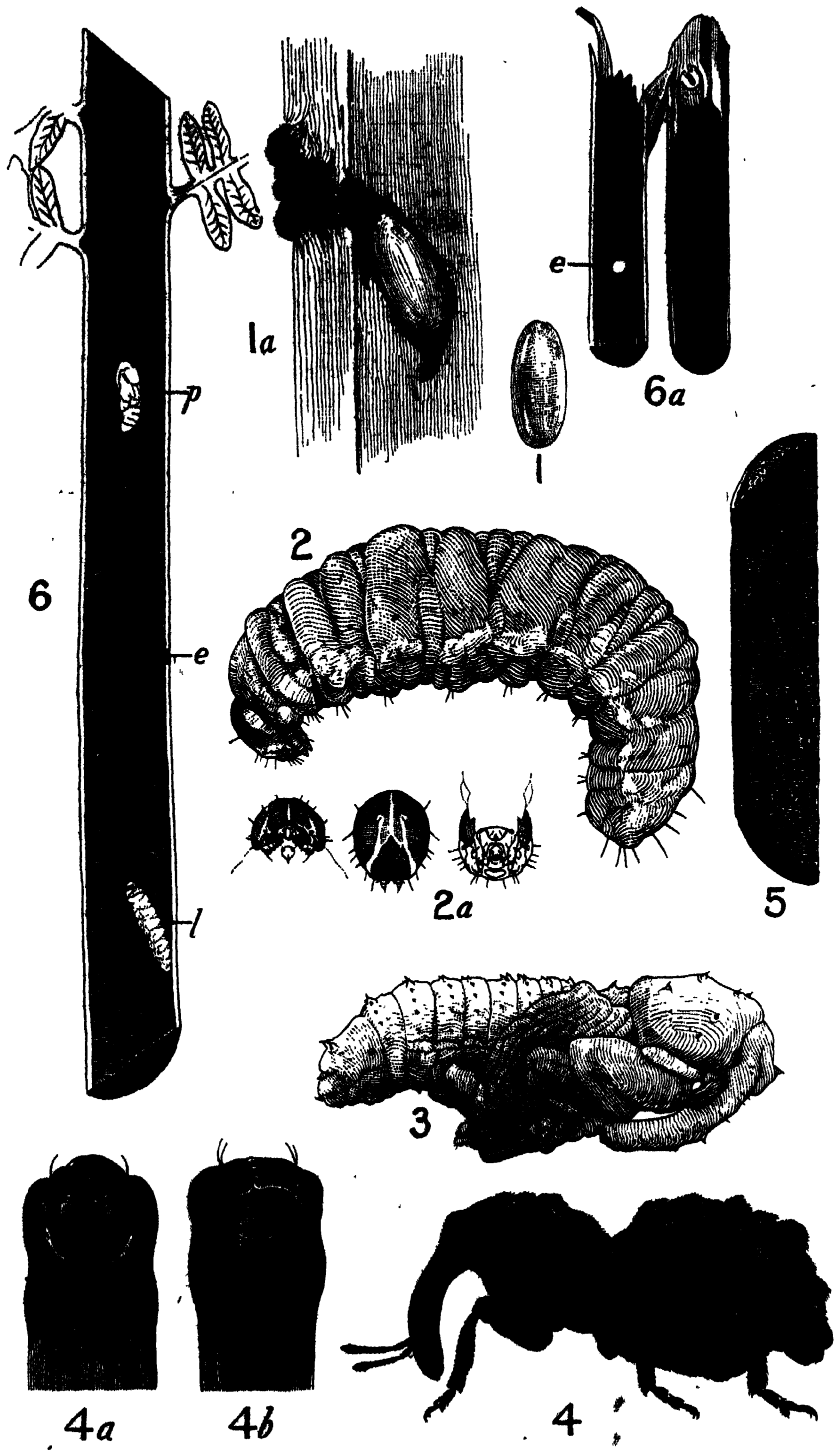
By D. T. Fullaway.†

Brief mention was made in the October *Forester* of the discovery, in September, of a serious infestation of the beautiful Sadleria ferns in the neighborhood of Kilauea by the Australian fern weevil, *Syagrius fulvitarsis,* and of the efforts made to suppress it. With the result of this undertaking still uncertain, a more troublesome situation is disclosed. The weevil, it is found, has escaped from one or two greenhouses in Hilo, to which it was supposed to be confined, and has spread all over the city, from Wainaku to Waiakea, on the fish-tail fern. It does not appear feasible to eradicate it in so extensive an area, and the only control measure which recommends itself at present is isolation, which may serve to protect the forests from invasion for a period. At all events, the possibility of invasion is no longer remote, and it seems important to consider now what the consequence would be should this beetle succeed in securing a firm foothold in the forests.

An examination of the Sadleria ferns in the mountains back of Honolulu, where the beetle has been present for 15 years, reveals the destructive nature of the insect. The fern growth there is thin, compared with that at Kilauea, yet it is impossible to find a single plant that has not suffered severely from the ravages of the beetle. As the attacks appear to be continuous, it seems certain that the ferns, in spite of their hardiness, will eventually succumb. At Kilauea, the shattered condition of the ferns was more noticeable on account of the thickness of the stand. In these dense forests, ferns constitute an important part of the ground cover. It is to be expected that their destruction will be followed by a train of attendant evils, such as the entrance of light, drying of the ground, the invasion of weeds, etc. The sensitiveness of the Hawaiian forests to disturbance is so well known that the result can be definitely predicted — a progressive debility of the trees on the edge of the invaded areas, a dying back of the forest, ultimately its extinction. It would seem necessary, therefore, to make every effort to prevent the fern weevil from gaining further access to the forests.

Illustrations of the different stages of the fern weevil accompany this article.

*The Hawaiian Forester and Agriculturist, January, 1920.
†Entomologist, Board of Agriculture and Forestry.



The Fern Weevil. (*Syagrius fulvitarsis* Pasc.) 1, Egg (greatly enlarged); 1a, section of fern stem showing egg-chamber (greatly enlarged). 2, larva; 2a, head of larva from front, above, and beneath, showing mouthparts (x10). 3, pupa (x10). 4, adult weevil (x10); 4a, b, apical ~~extremity~~ of rostrum showing mouthparts (greatly enlarged). 5, section of fern stem showing gallery of freshly-hatched larva (somewhat enlarged). 6, section of fern stem showing galleries of more advanced larvae and pupal chamber with exit; l, larva, p, pupa, e, exit (somewhat enlarged); 6a, portion of the preceding in greater detail.

Animal Cultivation at Hakalau.

Hakalau Cultivation Experiment. 1920 *Crop.**

In this test the following comparisons were made:

"A" plots—Regular plantation practice; offbarring, hilling-up, and all other animal work.

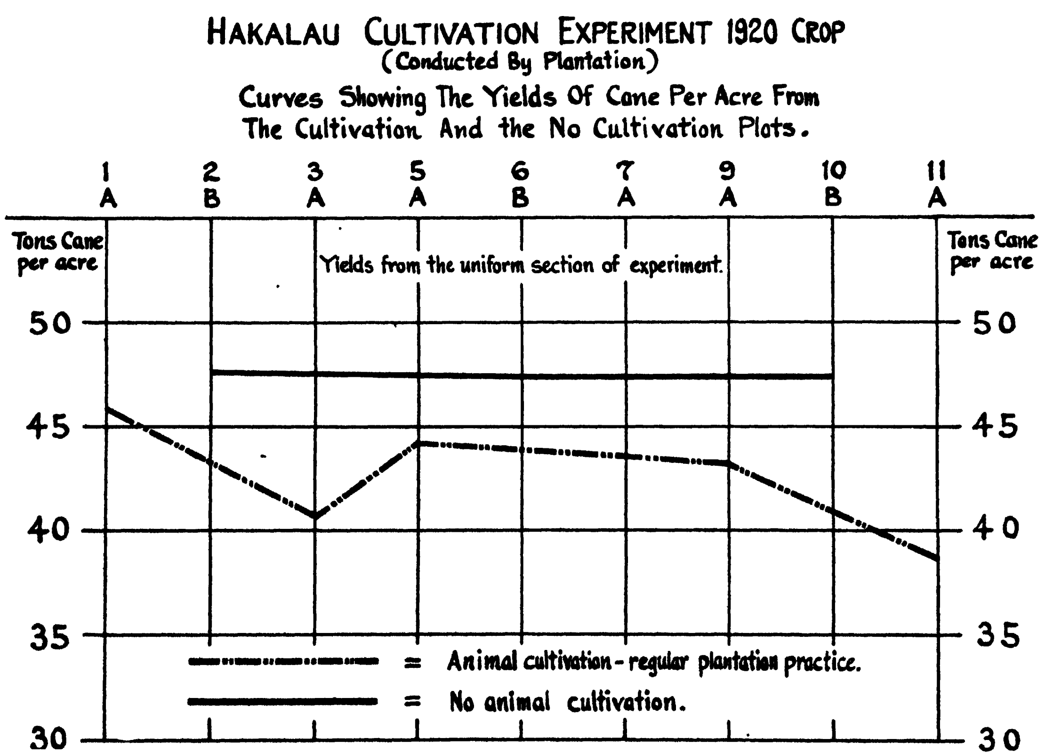
"B" plots—No animal cultivation; weeds controlled by hoeing and fertilizer covered by hand.

"C" plots—Not offbarred; all other animal work subsequently, as in "A" plots.

The results show a gain of 0.84 ton of sugar per acre for the plots receiving no animal cultivation as against the regular plantation practice. However, this increase was obtained at a higher cost, and was attended by an abnormal drain on the labor supply. The plots which were not offbarred produced one-half of a ton of sugar more per acre than did the plots which were offbarred.

An examination of the quality of the cane shows that the best juices were from the "no cultivation" plots, while the poorest juices were from the plots which received the most cultivation.

In experiments harvested at the Hilo Sugar Company last year (Planters'



*Experiment planned and conducted by plantation. Harvested by Mr. W. L. S. Williams.

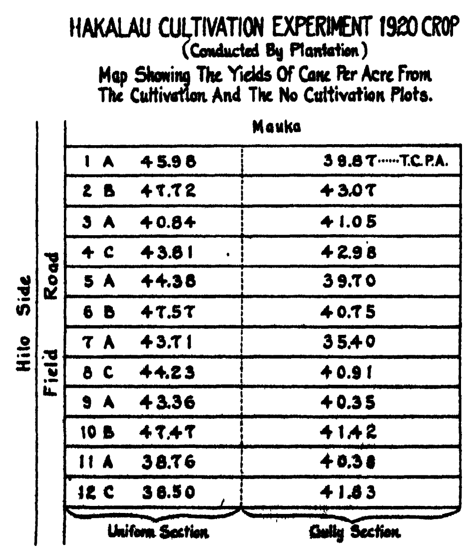
Record, Vol. XXI, page 153), results of an opposite nature were obtained—that is, the best juices were from the plots receiving the most cultivation, but in all cases those plots produced less cane.

The following summarizes the plot yields:

	Treatment	Tons Cane per Acre	Gain or Loss Over "A" Plots	Q. R.	Tons Sugar per Acre	Gain or Loss Over "A" Plots
Hilo side— Uniform section	A*	42.880	0	7.93	5.41	0
	B†	47.954	+ 5.074	7.37	6.51	+ 1.10
	C‡	42.114	— 0.766	7.46	5.64	+ 0.23
Hamakua side— Gully section	A	39.462	0	7.93	4.98	0
	B	41.750	+ 2.288	7.37	5.66	+ 0.68
	C	41.912	+ 2.450	7.46	5.62	+ 0.64
True average	A	40.723	0	7.93	5.14	0
	B	44.072	+ 3.349	7.37	5.98	+ 0.84
	C	41.978	+ 1.255	7.46	5.63	+ 0.49

*Regular plantation practice. †No animal cultivation. ‡No offbarring.

Careful records were kept as to the exact number of men and animals that were needed to perform the operations in this test. From these have been figured cost data which increase the value of the results of the experiment. In Table I is shown the number of men and animal hours used in each plot. In Table II there have been calculated the costs per acre based upon a charge of ten cents per hour for men, and eight cents per hour for animals, and the total cost per ton of sugar produced.



Summary of Results

	Plot	No. of Plots	Tons Cane Per Acre	Gain or Loss Over A Plots	Q. R.	Tons Sugar Per Acre	Gain or Loss Over A Plots
Hilo Side Uniform Section	A	6	42.88	0	7.93	5.41	0
	B	3	47.95	+ 5.07	7.37	6.51	+ 1.10
	C	3	42.11	- .76	7.46	5.64	+ .23
Hamakua Side Gully Section	A	6	39.46	0	7.93	4.98	0
	B	3	41.75	+ 2.28	7.37	5.66	+ .68
	C	3	41.91	+ 2.45	7.46	5.62	+ .64
True Average	A	6	40.72	0	7.93	5.14	0
	B	3	44.07	+ 3.34	7.37	5.98	+ .84
	C	3	41.97	+ 1.25	7.46	5.63	+ .49

Note:— A plots = Offbarred and regular practice.
B " = Not offbarred - no animal cultivation.
C " = Not offbarred - regular practice afterwards.

An anlysis of these figures shows:

(1) It cost $8.42 per acre more to care for the cane on the "B" plots (no animal work) than on the "A" plots (regular plantation practice). However, 0.84 ton of sugar more was produced on the "B" plots, which more than counterbalances the additional cost. Taking into consideration the cost per ton of sugar, the charge against the "A" plots is $3.45 as against $3.86 for the "B" plots.

(2) What were the items that went to make this additional cost for the "B" plots? First, the fertilizer was covered in the "B" plots at a cost of

$2.16 per acre. Second, there was required an extra hoeing in the "B" plots, which cost almost $7.00 per acre.

(3) From the figures of the "C" plots where offbarring was omitted, we note an interesting fact. It cost $2.13 per acre to give the first cultivation as against $0.70 per acre in the "A" plots, which were offbarred. It is common knowledge that it is always difficult to use cultivators or Horner harrows where the kuakua contains no loose earth, such as is thrown up by offbarring, to cover the weeds. This difference of $1.43 per acre between the "A" and "C" plots corroborates observations on this point.

In reporting on this experiment one must pay tribute to the late Robert Clark, of Hakalau Plantation Co., whose intense interest on the subject of cultivation contributed greatly to the success of this experiment.

TABLE I

DETAILED SCHEDULE OF MEN AND ANIMAL WORK IN HOURS FOR EACH PLOT.

	2-B	6-B	10-B	Average per Plot	Average per Acre
1st hoeing	16.50	16.50	16.50	16.50	47.60
2nd hoeing	16.00	16.00	16.00	16.00	46.20
3rd hoeing	24.00	24.00	24.00	24.00	69.30
Hoeing and stripping	16.00	16.00	16.00	16.00	46.20
Total hoeing	72.50	72.50	72.50	72.50	209.30
Covering fertilizer	7.50	7.50	7.50	7.50	21.65

TABLE I (Continued)

DETAILED SCHEDULE OF MEN AND ANIMAL WORK IN HOURS FOR EACH PLOT.

	4-C		8-C		12-C		Average per Plot		Average per Acre	
	A.	M.	A.	M.	A.	M.				
Offbarring	.....	....	.....	.....	.....	.....	......	......	......	......
Hilling-up	1.30	1.30	1.67	1.67	2.10	2.10	1.69	1.69	4.77	4.77
1st cultivation	9.00	9.00	9.25	9.25	10.10	10.10	9.46	9.46	26.72	26.72
2nd cultivation	1.67	1.67	1.75	1.75	2.33	2.33	1.91	1.91	5.39	5.39
Total	11.97	11.97	12.67	12.67	14.53	14.53	13.06	13.06	36.88	36.88
1st hoeing	.....	16.50	.....	13.50	.....	13.50	......	14.60	......	41.24
2nd hoeing	.....	16.00	.....	16.00	.....	16.00	......	16.00	......	45.20
3rd hoeing	.....	.....	.....	.....	.....	.....	......	......	......	......
Hoeing and stripping	.....	16.00	.....	16.00	.....	16.00	......	16.00	......	45.20
Total	.....	48.50	.....	45.50	.....	45.50	......	46.60	......	131.64

TABLE I (Continued)

DETAILED SCHEDULE OF MEN AND ANIMAL WORK IN HOURS FOR EACH PLOT.

	1-A		3-A		5-A		7-A		9-A		11-A		Average per Plot		Average per Acre	
	A.	M.	A.	M.	A.	M.	A.	M.	A.	M.	A.	M.				
Offbarring	2.00	1.33	2.00	1.33	2.50	1.67	3.00	2.00	3.00	2.00	3.75	2.50	2.70	1.80	7.86	5.24
Hilling-up	1.30	1.30	1.50	1.50	1.67	1.67	1.55	1.55	1.83	1.83	1.91	1.91	1.62	1.62	4.72	4.72
1st cultivation	2.50	2.50	2.75	2.75	3.00	3.00	3.14	3.14	3.25	3.25	3.50	3.50	3.02	3.02	8.80	8.80
2nd cultivation	1.60	1.60	1.75	1.75	1.67	1.67	2.00	2.00	2.00	2.00	2.25	2.25	1.88	1.88	5.47	5.47
Total	7.40	6.73	8.00	7.33	8.84	8.01	9.69	8.69	10.08	9.08	11.41	10.16	9.22	8.32	26.85	24.23
1st hoeing	.....	13.50	.....	13.50	.....	13.50	.....	13.50	.....	13.50	.....	13.50	......	13.50	......	39.30
2nd hoeing	.....	16.00	.....	16.00	.....	16.00	.....	16.00	.....	16.00	.....	16.00	......	16.00	......	46.60
3rd hoeing	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	......	......	......	......
Hoeing and Stripping	.....	16.00	.....	16.00	.....	16.00	.....	16.00	.....	16.00	.....	16.00	......	16.00	......	46.60
Total	.....	45.50	.....	45.50	.....	45.50	.....	45.50	.....	45.50	.....	45.50	......	45.50	......	132.50

TABLE II

DETAILED STUDY OF COSTS PER ACRE FOR EACH TREATMENT.

Plot	Offbarring			Hilling			1st Cultivation			2nd Cultivation			Total Cultivation Cost		
	Aml.	Men	T'tl.	Aml.	Men	T'tl.	Aml.	Men	T'tl.	Aml.	Men	T'tl.	Aml.	Men	T'tl.
A	$ .62	$ .52	$1.14	$ .38	$ .47	$ .85	$ .70	$ .88	$1.58	$ .43	$ .55	$ .98	$2.13	$2.42	$4.55
C	....	....	....	.38	.47	.85	2.13	2.67	4.80	.48	.53	1.01	2.99	3.67	6.66
B	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

TABLE II (Continued)

DETAILED STUDY OF COSTS PER ACRE FOR EACH TREATMENT.

Plot	1st Hoeing	2nd Hoeing	3rd Hoeing	Hoeing Strpng.	Cover Fert.	Total	Total Cost per Acre			Total Cost per Ton Sugar		
	Men	Men	Men	Men	Men	Men	Anml.	Men	Total	Anml.	Men	Total
A	$3.93	$4.66	....	$4.66	....	$13.25	$2.13	$15.67	$17.80	$ .41	$3.04	$3.45
C	4.12	4.52	....	4.52	....	13.16	2.99	16.83	19.82	.53	2.99	3.52
B	4.76	4.62	$6.93	4.62	$2.16	23.09	....	23.09	23.09	....	3.86	3.86

Details of Experiment.

Hakalau Cultivation Experiment. 1920 *Crop.*

Object:

To observe the value of cultivation operations, which are a part of the regular plantation practice.

Location:

Hakalau Plantation Co., Field 24.

Crop:

Yellow Caledonia, 1st ratoons.

Layout:

Number of plots = 12.

Size of plots = about 1/3 acre, consisting of 6 lines.

Plot	No.	Area	Plot	No.	Area	Plot	No.	Area
A	1	.3142	B	2	.3289	C	4	.3277
A	3	.3229	B	6	.3418	C	8	.3587
A	5	.3338	B	10	.3681	C	12	.3755
A	7	.3506						
A	9	.3647						
A	11	.3721						
Avg.		.3431			.3463			.3539

Plan:

Plots	Treatment
A	Regular plantation practice: offbarring, hilling-up and all other animal work.
B	No animal cultivation. Weeds controlled by hoeing and fertilizer covered by hand.
C	Not offbarred. All other animal work subsequently, as in "A" plots.

J. A V.–W. P. A.

Fertilizing First Ratoons Under Grove Farm Conditions.

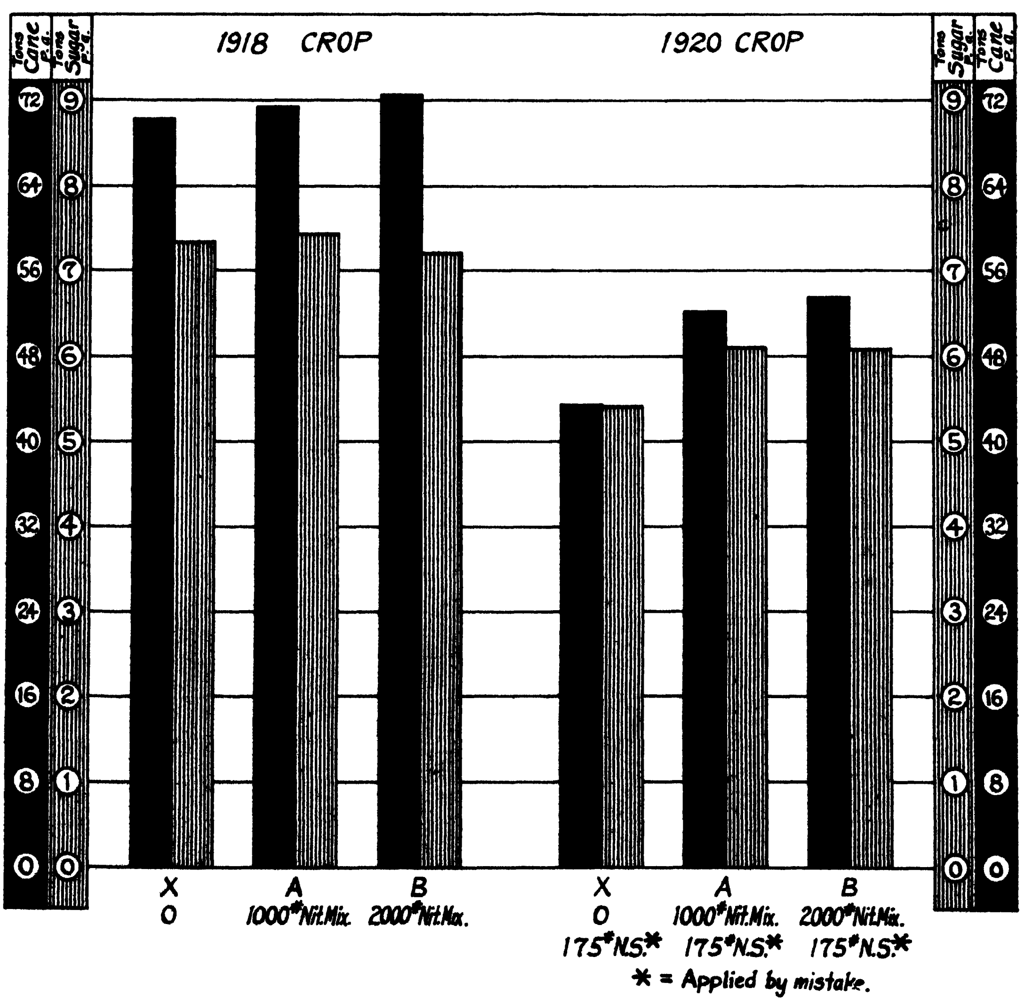
Grove Farm Experiments 2, 3, 4, and 5, 1920 Crop.

Summary.

These experiments consisted of a series of studies of nitrogen applications, including amount to apply, time of application, and forms of nitrogen. These experiments are continuations of those harvested in 1918, and reported in Record Vol. XIX, page 270.

The cane involved is D 1135, first ratoons. The previous crop was harvested in April, 1918, nothing further being done to the experimental area until the latter part of the following July, when the cane was hilled up, weeded, and irrigated,

FERTILIZER RESULTS WITH PLANT & THE FOLLOWING FIRST RATOONS.
GROVE FARM EXPERIMENT No. 2, 1918 & 1920 CROPS



without having been cut back. Fertilizations began in September. During October, 1918, 175 pounds of nitrate of soda (27 pounds of nitrogen) was uniformly applied by mistake in the irrigation water to all these experiments.

The results of the different treatments follow:

EXPERIMENT NO. 2 — AMOUNT TO APPLY.

Plots	Treatment	Yield per Acre			Gain Over No Fertilization	
		Cane	Q. R.	Sugar	Cane	Sugar
X	175 lbs. nitrate soda	43.4	8.02	5.42	0	0
A	1,000 lbs. nitrogen mixture plus 175 lbs. nitrate soda	52.3	8.55	6.12	8.9	.70
B	2,000 lbs. nitrogen mixture plus 175 lbs. nitrate soda	53.6	8.80	6.09	10.2	.67

EXPERIMENT NO. 3 — TIME OF APPLICATION.

Plots	Treatment	Yield per Acre		
		Cane	Q. R.	Sugar
A	1,000 lbs. nitrogen mixture in 4 equal doses, two first and two second season, plus 175 lbs. nitrate of soda	55.1	8.38	6.53
C	1,000 lbs. nitrogen mixture, in 2 doses; second season plus 175 lbs. nitrate of soda	57.5	8.86	6.49
D	1,000 lbs. nitrogen mixture, in 2 doses; first season plus 175 lbs. nitrate of soda	54.3	8.84	6.16

EXPERIMENT NO. 4 — AMOUNT TO APPLY SECOND SEASON.

Plots	Treatment	Yield per Acre		
		Cane	Q. R.	Sugar
C	500 lbs. nitrogen mixture, in 2 doses, plus 175 lbs. nitrate of soda	55.3	8.91	6.20
E	250 lbs. nitrogen mixture, in 2 doses, plus 175 lbs. nitrate of soda	56.1	8.52	6.59

EXPERIMENT NO. 5—FORMS OF NITROGEN.

Plots	Treatment	Lbs. of Nitrogen	Yields per Acre		
			Cane	Q. R.	Sugar
A	1,000 lbs. nitrogen mixture, in 4 equal doses: two first season; two second season, plus 175 lbs. nitrate of soda	150	56.1	8.99	6.24
F	1,000 lbs. nitrogen mixture, 1 dose, August, 1916, plus 175 lbs. nitrate of soda	150	57.7	8.90	6.49
G	1,250 lbs. blood; 12% nitrogen; one dose, August, 1916, plus 175 lbs. nitrate of soda	150	57.1	8.59	6.64

The nitrogen mixture used in the above experiments was 15% nitrogen (6% from nitrate of soda, 6% from sulfate of ammonia, and 3% from organic sources).

The results of experiment No. 2 show 177 pounds of nitrogen to give a gain of 0.70 ton of sugar over **27 pounds of nitrogen from nitrate of soda applied in the irrigation water in October,** while 327 pounds of nitrogen not only produces no further increase, but causes a slight loss, due to poorer juices. This is in marked contrast to the results of last crop, when fertilization produced no increase at all. This difference in response to fertilizer by plant and first ratoons is shown graphically in the accompanying cut.

It may be possible that even 177 pounds of nitrogen exceeds the profitable limit of fertilization, for comparing experiment No. 2 with No. 4, which is also amount to apply, though at different times, we find that 102 pounds nitrogen produce slightly better results than 177 pounds. The difference in yields between 102 pounds and 177 pounds is within the limits of experimental error, but it is interesting to note that the lesser amount produces as good results as the greater.

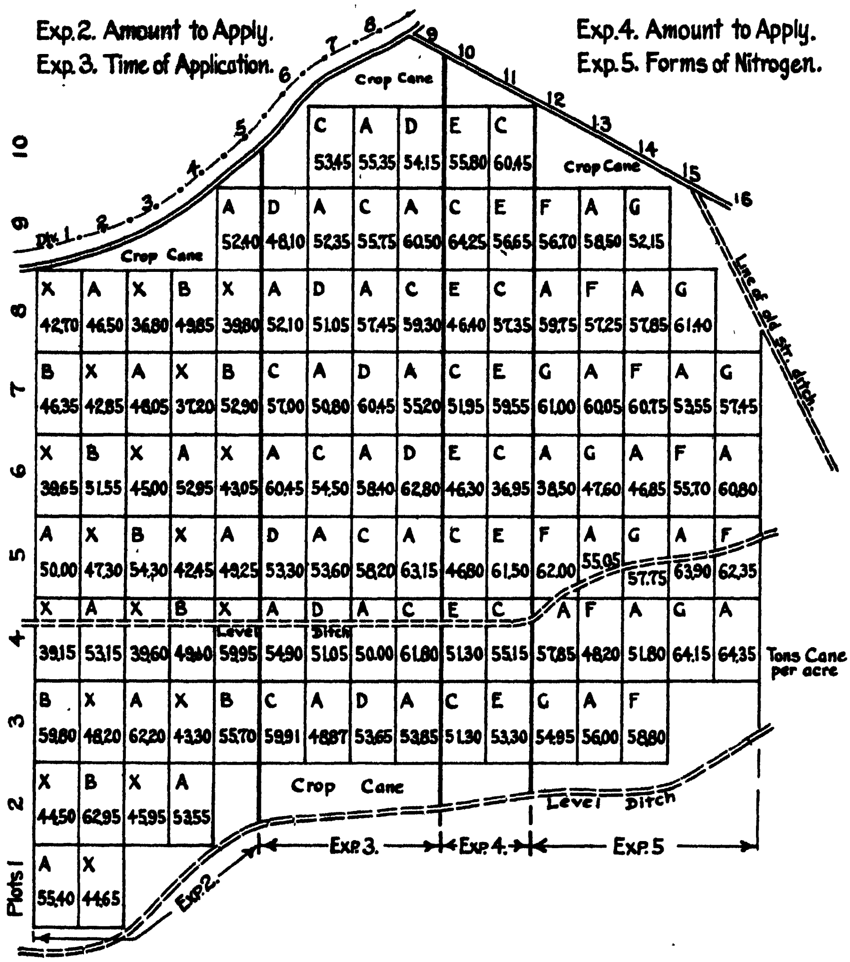
In experiment No. 3 the value of second season fertilization is clearly shown. The "D" plots, which received no fertilizer the second season, produced .37 ton less sugar than the average of the "A" and "C" plots, both of which received part of their fertilizer the second season.

The difference between the yields of the "A" and "C" plots,—a difference well within the limits of experimental error,—is so small that it gives no indication as to whether the fertilizer should be divided between the two seasons or all applied the second season.

In experiment No. 5, nitrogen in one dose (except for the small application of nitrate of soda in the water) from blood produces slightly better results than nitrogen mixture, either in one or several doses. The difference is due entirely to the quality of the juice. The difference in the amount of cane is well within the limits of experimental error.

These experiments are all to be continued for another crop.

GROVE FARM EXPERIMENTS 2, 3, 4 & 5, 1920 CROP



Summary of Results (Exp. 2.)

Plot	No. of Plots	Treatment	Lbs. N. S. Oct. 1918	Tons P.A. Cane	Q.R.	Tons P.A. Sugar
X	18	No fertilizer	175	43.45	8.02	5.42
A	10	1000# Nitrate Mixture	175	52.35	8.55	6.12
B	9	2000# Nitrate Mixture	175	53.60	8.80	6.09

Summary of Results (Exp. 3.)

Plot	No. of Plots	Treatment	Lbs. N. S. Oct. 1918	Tons P.A. Cane	Q.R.	Tons P.A. Sugar
A	15	150#N. Both seasons in 4 equal doses	175	55.13	8.38	6.58
C	8	150#N. 2nd season in 2 equal doses	175	57.49	8.86	6.49
D	8	150#N. 1st season in 2 equal doses	175	54.32	8.84	6.15

Summary of Results (Exp. 4.)

Plot	No. of Plots	Treatment	Lbs. N. S. Oct. 1918	Tons P.A. Cane	Q.R.	Tons P.A. Sugar
C	8	150#N. 2nd season in 2 equal doses	175	55.28	8.91	6.20
E	8	75#N. 2nd season in 2 equal doses	175	56.10	8.52	6.59

Summary of Results (Exp. 5.)

Plot	No. of Plots	Treatment	Lbs. N. S. Oct. 1918	Tons P.A. Cane	Q.R.	Tons P.A. Sugar
A	14	150#N. Both seasons in 4 equal doses	175	56.13	8.99	6.24
F	8	1000# Nit. Nac. 1st season in 1 dose	175	57.72	8.90	6.49
G	8	1250# Blood 1st season in 1 dose	175	57.06	8.59	6.64

Details of the Experiments.

Grove Farm Experiment No. 2 (1920 Crop).

Fertilizer Experiment—Amount to apply to first ratoons. (O. 150, 300 lbs. nitrogen per acre.)

Object:
To determine the most profitable amount of nitrogen per acre to apply to ratoon cane under Grove Farm conditions.

Location:
Field 6.

Crop:
D 1135, 1st ratoons.

Layout:
Number of plots, 37.
Size of plots, 1/10 acre each (48.3'x90.2'). Rows irregular; plots one water course wide.

Plan:

FERTILIZATION* IN POUNDS PER ACRE PER APPLICATION.

Plots	No. plots	Aug. 1918	Oct. 1918	Nov. 1918	Feb. 1919	May 1919	Total Lbs. Nitrogen
X	18	0	†175	0	0	0	27
A	10	250	†175	250	250	250	177
B	9	500	†175	500	500	500	327

*Fertilizer used, 15% nitrogen (6% nitrate, 6% sulfate, 3% organic).
†Nitrate of soda.

Progress:

Sept. 22, 1918—First fertilization.
Oct. 1918—All plots, by mistake, received 175 lbs. nitrate of soda in irrigation water.
Dec. 19, 1918—Second fertilization.
Feb. 4, 1919—Third fertilization.
June 6, 1919—Fourth fertilization.
March, 1920—Experiment harvested by J. H. Midkiff.

Grove Farm Experiment No. 3 (1920 Crop).

Fertilizer Experiment—Time of application.

Object:
To determine the best time to apply a given amount of fertilizer to ratoon cane.

Location:
Field 6.

Crop:
D 1135, 1st ratoons.

Layout:
Number of plots, 31.
Size of plots, 1/10 acre each (48.3'x90.2'). Rows irregular; plots one water course wide.

Plan:

FERTILIZATION*— POUNDS FERTILIZER PER ACRE

Plots	No. plots	Aug. 1918	Oct. 1918	Nov. 1918	Feb. 1919	May 1919	Total Lbs. Nitrogen
A	15	250	†175	250	250	250	177
C	8	0	†175	0	500	500	177
D	8	500	†175	500	0	0	177

*Fertilizer used: 15% nitrogen (6% nitrate, 6% sulfate, 3% organic).
†Nitrate of soda.
Experiment planned by R. S. Thurston and J. A. Verret.

Progress:

Sept. 22, 1918—First fertilization.
Oct. 1918—All plots, by mistake, received 175 lbs. nitrate soda in irrigation water.
Dec. 19, 1918—Second fertilization.
Feb. 4, 1919—Third fertilization.
June 6, 1919—Fourth fertilization.
April, 1920—Experiment harvested by J. H. Midkiff.

Grove Farm Experiment No. 4 (1920 Crop).

Fertilizer Experiment—Amount to apply second season.

Object:

To determine the most profitable amount of fertilizer to apply to first ratoons during the second season.

Location:

Field 6.

Crop:

D 1135, 1st ratoons.

Layout:

Number of plots, 16.
Size of plots, 1/10 acre each (48.3′x90.2′). Rows irregular; plots one water course wide.

Plan:

FERTILIZATION*—POUNDS PER ACRE

Plots	No. plots	Aug. 1918	Oct. 1918	Nov. 1918	Feb. 1919	May 1919	Total Lbs. Nitrogen
C	8	0	†175	0	500	500	177
E	8	0	†175	0	250	250	102

*Fertilizer, 15% nitrogen (6% nitrate, 6% sulfate, 3% organic).
†Nitrate of soda.
Experiment planned by R. S. Thurston and J. A. Verret.

Progress:

Oct. 1918—All plots received, by mistake, 175 lbs. nitrate of soda, in irrigation water.
Feb. 4, 1919—First fertilization.
June 6, 1919—Second fertilization.
April, 1920—Experiment harvested by J. H. Midkiff.

Grove Farm Experiment No. 5 (1920 Crop).

Fertilizer Experiment—Forms of nitrogen.

Object:

To compare the value of equal amounts of nitrogen from: (1) Organic; (2) nitrogen mixture.

Location:
Field 6.

Layout:
Number of plots, 30.
Size of plots, 1/10 acre each (48.3′x90.2′). Plots one water course wide and rows irregular.

Plan:

FERTILIZATION—POUNDS PER ACRE.

Plots	No. plots	Fertilizer	Aug. 1918	Oct. 1918	No. plots	Aug. 1918	Oct. 1918	Total Lbs. Nitrogen
A	14	N. mixture	250	†175	250	250	250	150
F	8	N. mixture	1000	†175	....	....	....	150
G	8	Blood	1250	†175	....	....	....	150

†Nitrate of soda.
Nitrogen mixture = 15% nitrogen (6% nitrate, 6% sulfate, 3% organic).
Dried blood = 12% nitrogen.
Experiment planned by R. S. Thurston and J. A. Verret.

Progress:

Sept. 22, 1918—First fertilization.
Oct. 1918—All plots received, by mistake, 175 lbs. nitrate of soda in irrigation water.
Dec. 17, 1918—Second fertilization.
Feb. 4, 1919—Third fertilization.
June 6, 1919—Fourth fertilization.
April, 1920—Experiment harvested by J. H. Midkiff.

J. A. V.-R. S. T.

Plantation Rehabilitation.

By Donald S. Bowman.*

One of the great problems that confronts the sugar estates today is the completion of the rehabilitation program which has been under way a number of years. Much has been done to ameliorate conditions, and this has no doubt increased the efficiency of the labor and produced a greater general feeling of contentment in so far as living conditions are considered. The complicated growth of the social and industrial relations of this Territory makes some form of paternalism inevitable. We are duty bound to protect the general health and well-being of our imported labor. This fact has been long recognized, leading up to the splendid system of housing and sanitation in force today, which, if continued, will place us in a few years in the front rank of industries that maintain ideal housing conditions, thus placing the plantations in such a position that the industrial housing laws of the United States will have been complied with. The Industrial Service Bureau's Sanitary and Building Code, together with the general recommendations, if followed, complies quite fully with the "standards recommended for permanent industrial housing developments" by the Department

*Industrial Service Bureau, H. S. P. A.

of Labor, U. S. Government. It is quite evident that the Department of Labor will soon have general jurisdiction over industrial housing. The work of the Bureau of Industrial Housing, created by the Department of Labor in June, 1918, under whose directions some $100,000,000.00 was expended for general community utilities and housing of government employees in arsenals, navy yards, etc., met with marked success, and the completed villages were in every way far superior to those undertaken by private corporations who had expended the same amount of money without careful consideration of the ultimate outcome and without obtaining proper advice on village planning. This comparison has done much to awaken in the minds of those interested in industrial housing the need of governing laws.

The building of new dwelling houses is not the greatest problem we have, as plans are at hand and new material can be easily handled. The difficulty arises

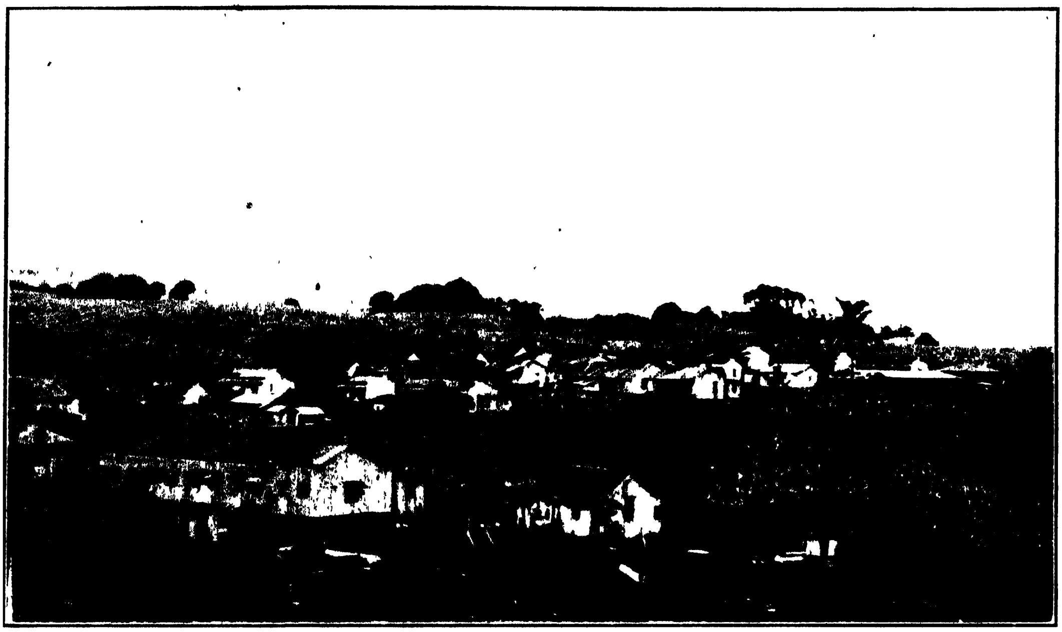
Type of one-family house (Plan 11) now under construction to replace barracks being removed. These attractive houses will face on a macadam road, and be provided with sufficient yard and garden space.

when we consider reconstruction—what buildings may be made to answer modern requirements—how to get away from the open-fire smoke-box kitchens and provide an economical, practical kitchen, well ventilated, free from smoke, etc. The disposal of waste water and fecal matter is another vital problem, and this cannot be accomplished without some labor and expense; but the returns in cleanliness, comfort, and health make an intelligent expenditure of labor and money for such a purpose one of the best possible investments.

More attention should be paid to the rebuilding and grouping of the houses. This can best be cared for by making a careful survey of the camp and planning all improvements in advance, in order that the completed work will be harmonious in the whole. A careful survey will no doubt show that many of the old buildings can be reconstructed, while others will have to be demolished entirely. The principal points to consider in the rehabilitation of a camp are: dwellings that meet with the requirements of the building code, laws and standards, as to construc-

tion and location; outhouses that are sanitary and convenient; drains and sewers that are sanitary and practicable for plantation use; water supply that is safe. The general layout of streets, drains, etc., as well as the location of buildings, should receive careful consideration.

A careful study of these and other problems that confront the plantation manager in his consideration of rehabilitation has been made by the Industrial Service Bureau, who are prepared to assist with plans, suggestions, etc.



Old plantation camp undergoing rehabilitation; barracks and shacks being removed; two-family houses remodeled. New type dwellings may be seen on extreme right. Space in center of camp now in cane to be devoted to gardens.

A housing survey of one plantation brings to light the fact that ninety per cent of the dwellings are of good construction, provided with the proper light and ventilation, but owing to a bad type of detached kitchen and many lean-tos added by the laborers, most of the dwellings have a decidedly dilapidated appearance, but they are not beyond recall when it comes to remodelling.

Protecting Boiler Drums From Overheating.*

A bulged spot on a boiler shell is not an uncommon occurrence. We associate it usually with the fire sheets of horizontal tubular boilers, the crown sheet of locomotive boilers, and in general with the furnace tops of internally fired boilers. The cause may be either shortness of water or an accumulation of oil, mud, or scale. When a steel plate or a steel tube is exposed to the hot products of combustion on one side, and is covered with water on the other side in a well-

*Reprinted from *The Locomotive* of the Hartford Steam Boiler Inspection and Insurance Company in *The Boiler Maker,* March, 1920.

designed boiler, heat is transmitted from the hot gases and from the radiating fuel bed through the metal to the water at a sufficiently rapid rate to keep the temperature of the metal well below the range at which it begins to lose its strength and become soft and plastic. If, however, some substance comes between the metal and the water which cannot remove the heat from the metal as fast as it is received from the fire and the hot gases, the metal becomes gradually hotter till a point is reached at which it is no longer able to withstand the stresses imposed by the steam pressure within the boiler and the plate or tube swells out into a bulge. If the bulged metal continues to receive heat at a faster rate than it can dispose of it, the bulge increases in size and the metal wall gets thinner and thinner until it ruptures at the weakest point.

Common Causes for Bulging.

There are many different conditions which may result in a bulged spot in a boiler, and, since the portion of the boiler directly exposed to the action of the flame and combustion products is usually below the normal water line, we are apt to look for this condition only at such points. The most common cause for bulges below the normal water line of a boiler is, of course, a deposit of some sort of heat-resisting material on the water side of the metal. This may be an oil film or it may be a deposit of mud or scale matter from the boiler water. In either case if it provides sufficient hindrance to the flow of heat a bulge will result. Another common cause for the bulging and rupturing of boilers is found in some abnormal working condition which permits the water line to become dangerously low. Under these circumstances as soon as steam and not water covers the surface of metal exposed directly on the opposite side to the heat of the products of combustion, overheating of the metal, which will result in bulging and rupture, is likely to start, because heat cannot flow as readily through a metal and into steam as it can flow through the same metal and into water.

Superheating Surface.

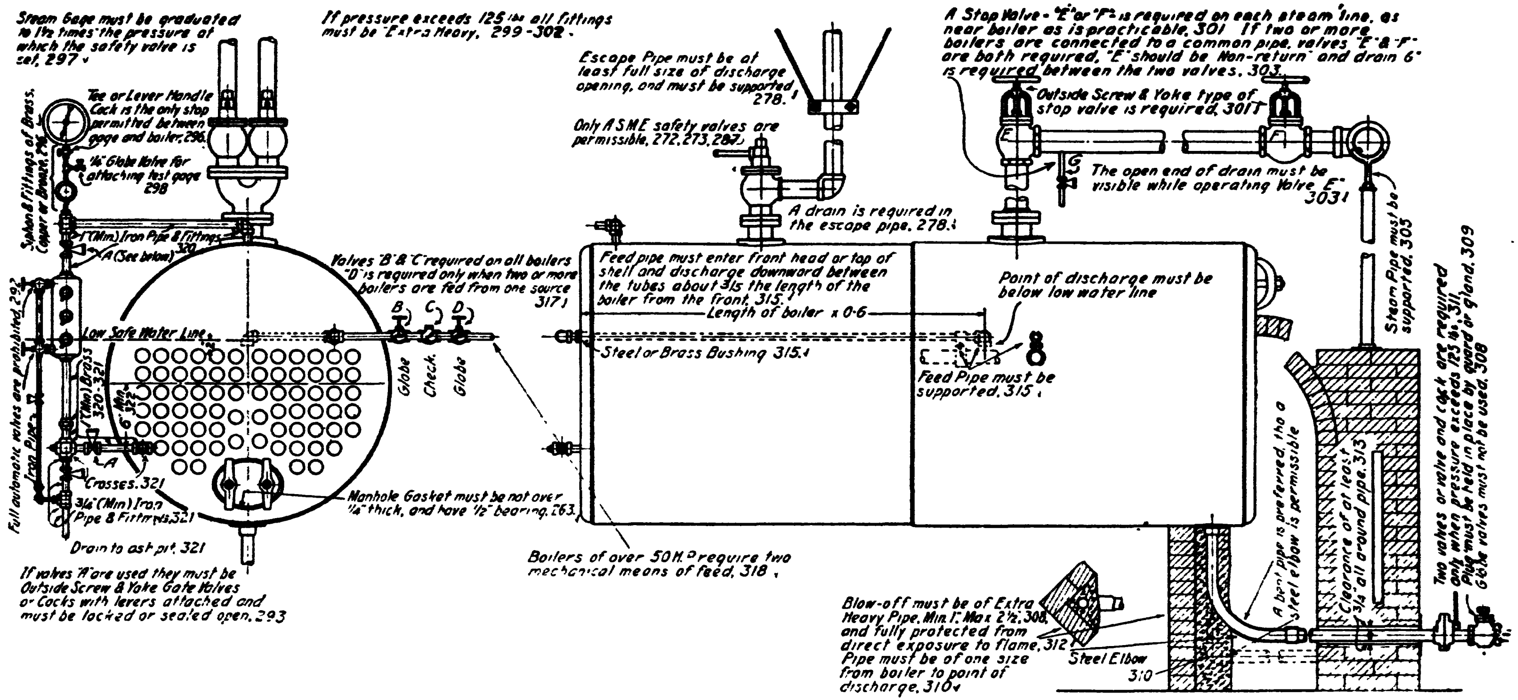
To be sure, superheaters are made in various ways with special provisions for the rapid absorption of heat by the steam and for considerable reserve strength to resist the tendencies to bulge on the part of the metal, in which heat can be safely and profitably transmitted directly from the hot gases to steam through the metal. It is also true that a properly designed vertical firetube boiler may have a portion of the upper end of the tubes exposed on the one side to the steam and on the other to hot gases with no serious results. In general, however, a portion of a shell or drum of a boiler, whether of the firetube or watertube type, which is exposed to combustion products on one side and is not covered by water on the other side is apt to prove troublesome, if not dangerous.

Three-Pass Setting.

Formerly it was common in some parts of the country to return the gases from an ordinary horizontal return tubular boiler from the front end after they had passed through the tubes directly back across the top of the boiler in a brick

BUREAU OF BOILER INSPECTION.

Minimum requirements for newinstallations of horizontal return tubular boilers and suggestions for safety for present installed boilers.



flue of which the upper surface of the boiler shell was a floor, to a stack connection at the back. This arrangement has been known locally as a three-pass setting. It probably succeeded in running without serious injury to the boiler (when it did so succeed) chiefly because the gases were pretty well cooled before they emerged from the tubes at the front end, and also because as the boiler shell formed the bottom of the third pass it must inevitably become heavily blanketed with soot and fine ash in an exceedingly short time. Soot and ash are rather better insulators to heat flow than many forms of pipe covering, and so the top of the shell usually became protected with soot. When it is remembered that if soot enough was deposited on the boiler top to protect the shell plates there would certainly be enough of it to practically prevent any possible economy through the additional absorption of heat from gases by the steam. Also, since the supposed extra absorption of heat was the only reason for providing the extra gas pass, a matter of some expense and much inconvenience, as such a pass greatly complicates the provision of proper and accessible manholes and the location of a safety valve close to the boiler shell, there is no great difficulty in seeing why its use is rapidly declining even in the regions where it had become a nearly standard method of installing boilers.

The Protection of Boiler Drums.

When horizontal tubular boilers are set, care is taken that the brick work of the settings shall come close enough to the boiler shell so that the joints can be tightly packed with asbestos rope. The line at which the brick setting and the shell are joined through this packed joint is about where a horizontal plane through the horizontal diameter of the head would cut the shell, and this is several inches below the usual working water line. In the event of low water, several rows of tubes would be exposed to the fire before any unprotected portion of the shell comes in contact with hot gases. However, in some sorts of watertube boilers the settings are so arranged that parts of the space open to the gases are in contact with portions of the surface of steam drum, which are not always covered with water on the steam side. This condition may be aggravated at times of heavy load by the fact that the water line is not uniform throughout all parts of a watertube boiler, but may rise, due to the effect of the rapid circulation in some of the tubes and drums or in some portion of the boiler, only to correspondingly fall at other points. The amount of this rise and fall varies with the rapidity of the circulation and the load on the boiler. A further condition to be reckoned with is the fact that, although where the rate of combustion is moderate and the furnace conditions good, combustion may be completed long before the gases reach the relatively out-of-the-way corners where the shell surface is exposed above the water line. Still, under overload conditions, or with poor firing, an entirely different set of circumstances may arise.

Secondary Combustion.

It is not uncommon for a portion of the fuel bed to give off combustible gas in a solid stream at a rapid rate. This solid stream may easily pass through a considerable part of the combustion space without burning. It will do this,

for example, if it is not properly mixed with air; for gas cannot burn without air, no matter how hot the surroundings. If such a stream of hot combustible gas gets up into the corners of the setting and there finds air which is perhaps leaking through small cracks in the brick or tile, it will often burst into flame and burn strongly at these points, notwithstanding that it has come a long way from the main part of the fire. Such burning of combustible gas when boilers are being forced on coming in contact with air is the thing which is occasionally seen as a flame at the top of the stack, especially in the case of gas retorts and foundry cupolas, and is known as secondary combustion. It should be clear that if secondary combustion occurs in a corner of a boiler setting alongside of a portion of the boiler shell and above the water line, serious and perhaps dangerous bulging of the shell is the result to be expected, probably also followed by a more or less violent rupture. Indeed, such a rupture might easily be sudden and large enough to start a boiler explosion, for, once released, there would be abundant energy stored in the hot water and steam within the boiler to continue the destruction.

The Obvious Cure.

In any case, even if the rupture were a small one, resulting only in the gradual release of the steam from the boiler, the accident would prove inconvenient and expensive. The means for preventing such accidents is simple and should be obvious. It consists merely in carefully studying the setting of a boiler to see if it is possible that the water line in ordinary operation can drop low enough to expose portions of the shell unprotected by water to the gases. If this is possible the setting should be changed immediately so that this contact will become impossible. [W. E. S.]

Superheated Steam.*

By Gustavo Lobo.†

The article on the subject of superheated steam which appeared in your issue of January 3 should be of great interest to sugar factory engineers and owners, and the writer certainly has brought out in concise form the principal advantages of superheat in this type of plant.

There is one point, however, touched upon in your article which, I believe, could be somewhat amplified so as to bring out its great importance. I refer to the decided advantages of the use of superheated steam in an electrified sugar mill—that is, one operated electrically and with a central electric generating station in which are installed steam turbo-generators.

In addition to the value of superheated steam as a means of increasing the

*Facts About Sugar, March 13, 1920.
†President of the Kelvin Engineering Company.

efficiency of the turbine, with the consequent reduction of the cost of power and of furnishing a drier exhaust for use in the heaters and evaporators, attention should be called to the great value of superheated steam in diminishing or avoiding completely the wear of the turbine blades, due to entrained moisture.

If for nothing else, the use of superheated steam in turbines would be worth while for this reason alone, as erosion of blading is almost entirely done away with, the maintenance cost of the turbine very greatly reduced, and the possibilities of breakdown from that cause practically eliminated.

As a result of the experience of several years in the construction and operation of electrified sugar factories, I can safely say that there have been no troubles or shut-downs due to blade wear in factories where superheated steam is used, whereas in those factories which have been using dry saturated steam there have often been difficulties, and even at times lengthy shut-downs, due to the wear occasioned by the moisture in the steam.

In regard to the increased efficiency due to the superheat, I would say that this is corroborated by the guarantees offered by the turbine builders, whose specifications stipulate that the efficiency of the turbines will be increased two per cent for each one per cent of moisture which is eliminated from the steam.

[R. S. N.]

The Yellow Stripe Disease.*

A Report of an Investigation Into Its Prevalence in Porto Rico.

By Noel Deerr.

Early History of the Disease.

As far back as the beginning of organized research in Java about 1895, a condition known as yellow stripe was recognized. The botanists there have never treated the condition as a specific disease, but have regarded it as a sporting tendency possessed by the cane, that is to say, they believed that the cane had the habit of throwing leaves deficient in chlorophyll. They recognized the inheritance of the condition in so far that it was observed that cuttings taken from canes which had shown the yellow stripe tended to give a crop with a greater percentage of yellow striped canes and that when cuttings from unaffected canes were used the condition tended to disappear. Experiments made in Java negatived the presumption that the disease was infectious, or that it was caused by any specific organisms.

About 1909 Dr. H. L. Lyon, the plant pathologist attached to the Experiment Station of the Hawaiian Sugar Planters' Association, made an extended tour of investigation through Australasia and Java for the purpose of gaining information on cane diseases and kindred matters at first hand. He recognized that the

*Facts About Sugar, Vol. X, Nos. 10, 11, 12.

yellow stripe condition also was present in Hawaii and on his return he instituted a series of experiments. Contrary to the Java experience, he found that the disease was infectious. He also determined the loss due to the disease in a large number of varieties, examined the susceptibility and resistance of the same and advised, as a means of control, seed selection and the rejection of those varieties found to be susceptible, independent of any other desirable features that they possessed. In addition the introduction and exchange of seed cane from areas known to be infected was discountenanced. I believe that it was due to the early recognition of the possible danger of the disease that the Hawaiian Islands were saved from such an epidemic as is now prevailing in Porto Rico. Nevertheless the latest advices I have from Hawaii indicate that the disease is slowly gaining, especially in one district where conditions seem to be favorable to its development.

Identity of the Disease.

The manifestations of the disease being so different in Porto Rico from what they have been in Java and Hawaii has led to doubt as to their identity. Of this there seems to be no doubt whatever, as the published descriptions from Java are in so great detail and correspond exactly with the lesions that are observed in Porto Rico, the difference being in extent only. This point has been discussed in full detail by Mr. Colon, in one of the publications of the insular station. The reasons for the different behavior of the disease in Porto Rico will appear from remarks that follow later.

Plantation Practice in Java as Differing From That in Porto Rico Considered in Relation to the Yellow Stripe Disease: The peculiar methods used in Java in plantation routine undoubtedly have protected the industry there, and as these bear on the condition in Porto Rico, some mention of them is apposite. In Java substantially all cane grown is planted cane, and cane is only grown on the same land at the most one year in every three, the land during the other two years being under rice and ground provisions. In such a system any organism parasitic on the cane is denied its host for two years out of three, and must therefore tend to disappear for lack of a suitable habitat. With the system common in Porto Rico (and elsewhere) of cane following cane, any parasitic organism has a continuous habitat, and not only does it have the opportunity of increasing in number, but it is also afforded the opportunity of developing a strain specifically virulent to the host plant.

A second control factor is the system that has developed in Java of growing seed cane in mountain nurseries remote from plantations and so removed from any source of infection. This system was originated as a means of controlling the "sereh" disease, and doubtless, though not of intent, has been equally adequate in preventing the spread of the yellow stripe.

Thirdly, I believe that in the selection of new seedling varieties in Java attention was paid to the appearance of yellow stripe considered as an undesirable feature, so that while the new Java varieties probably are not immune, they are resistant and not liable to be severely affected by the disease.

These differences in routine, accompanied by the extraordinary care used in Java in inspecting each cutting used for seed (a process possible with the exceptionally cheap and abundant labor), fully account for the differences observed

between Java and Porto Rico, and at the same time suggest a basis for methods of control, some of which have already been put into application.

Introduction Into West Indies.

There does not seem to be any doubt but that the disease has been only recently brought into the West Indies. No one of the many older planters whom I met had any recollection of seeing the disease previous to 1916, and hence it is very probable that the disease has been imported along with some recently introduced varieties. Amongst these are a number of varieties recently brought from the Argentine through, I believe, the agency of the United States Department of Agriculture. These varieties include some Java seedlings brought to the Argentine by way of Egypt, and the yellow stripe disease now known to be prevalent in the Argentine is also known to be of recent occurrence in Egypt. In addition, Mayaguez seems to have been a focus of infection and both Fajardo and Guanica were of opinion that the primary infection on these properties came with seed cane from the federal station.

It was in 1914 that these importations were made, and at first sight the rapid spread of the disease seems to have been remarkable. It is, however, an established fact with disease of all types that a parasite introduced into a locality where it has not been previously present often develops a fulminant form. This phenomenon is explained by the faculty possessed by living organisms of developing immune strains, thus forming an example of the general principle of the "survival of the fittest." Under this conception the stock in Java, where the disease has been long established, may be regarded as having produced more or less resistant types, due to the elimination of susceptible strains. In Porto Rico, however, where the disease has not been present, there will have been no opportunity for the weeding out of susceptible strains, so that the introduction of a parasite will be likely to be followed by an epidemic.

The Position of Cuba.

The introduction to Cuba may also be ascribed to similar importations but of these I have no exact knowledge, only knowing that such have occurred recently.

Dr. E. W. Brandes, in Bulletin 829, U. S. Department of Agriculture, states that the disease has been present in Cuba for at least twenty years. He mentions Santiago de las Vegas and Cienfuegos as the localities where it is most prevalent. and to these I can add Jobabo, where I recognized the disease as appearing sporadically in isolated areas in 1915. It is very remarkable that the disease has become epidemic so rapidly in Porto Rico, while up to the present there is no report of an epidemic stage in Cuba. This cannot be attributed to immunity, since the crystalina cane planted everywhere in Cuba has been found to be very susceptible in Porto Rico. Possibly the explanation may lie in the lack of extension of the introduced varieties, since nearly the whole of Cuba is planted with "native" stock and the introduced varieties have been but sparsely applied.

At the same time it is to be remembered that the means of transmission of the disease is as yet unknown, and there may be some factor present in Porto Rico which is absent in Cuba.

Cuban Situation Dangerous.

Although I have not been in Cuba for three years, I wish to go on record as stating that the presence of the disease there should be treated as a source of danger, and specifically I would say:

(1) It should be recognized that the disease exists in Cuba in widely separated localities, but that it has not yet reached any great extension.

(2) Judging from previous experience a rapid spread of the disease *may* at any time occur.

(3) The widest publicity should be given to the facts in such a way as to advise of the danger, while at the same time avoiding any tendency to panic.

(4) All interested parties should be on the alert to detect the first symptoms of any outbreak of the disease, and when any such appears the system of eradication advocated by Mr. Earle should be applied.

(5) Unless the disease has made much more headway than the reports to hand lead me to believe, I think that the situation can be handled, provided the lessons to be learnt from the situation in Porto Rico be not neglected.

Extent in Porto Rico.

The itinerary I followed in Porto Rico took me over a great part of the cane areas and it was a matter of easy observation to see that nearly the whole island is infected. The lands controlled by the Fajardo Company are nearly if not quite free from the disease, and up to the present it has made no great progress at Aguirre. Otherwise wherever I went the disease was thoroughly established. This includes the south coast, west of Aguirre, the west coast, the line running north from Ponce to Arecibo, and the north coast up to and including the lands controlled by the Loiza Sugar Company where the disease is of very recent appearance amongst the colonos' cane.

Indeed, the only extensive areas I saw free from disease were the lands of the Fajardo Company, and here unfortunately some cane belonging to independent growers, such as that at Maizalles, and contiguous to Fajardo fields is very badly infected. A similar focus of infection was shown me by Mr. Carpenter at Cortada where a badly infected field belonging to the Santa Isabel Company abuts the fields planted by Aguirre. This interlocking of properties forms a serious factor in the control of the disease, and is all the more serious where there happens to be a number of small planters of less intelligence, since it seems quite possible that these scattered small infected areas may be a factor of importance in determining the secondary infection of other areas planted from disease free seed.

The Effect of Climate.

Before leaving New York for Porto Rico I had learned that the years 1917 and 1918 had been deficient in rainfall. It had also been suggested that the remarkable decrease in output as between the years 1917, 1918, and 1919 was mainly due to the drouth and that the effect of the disease had been exaggerated.

I, therefore, obtained the statistics of the United States Weather Bureau and collated these as regards the northern and western districts, where the dis-

ease had been known to have been severe. These data are to be found in the appended exhibit and you will note:

NON-CONNECTION OF CLIMATE AND OUTPUT

Rainfall and Crops in West Porto Rico

Year	1915	1916	1917	1918
Number of rainy days	110	144	159	149
Inches rain	76.6	80.2	78.4	76.4
Year	1916	1917	1918	1919
Tons of sugar produced*	27,508	32,405	21,896	19,632

*From Centrals Rochelaise, Ana Maria, Corsica, Eureka, selected as known to be affected by the disease.

Rainfall and Crops in North Porto Rico

Year	1915	1916	1917	1918
Number of rainy days	188	191	180	175
Inches of rain	82.8	89.0	71.8	63.9
Year	1916	1917	1918	1919
Tons of sugar produced*	84,271	77,509	62,516	50,244

*From Centrals Cambalache, Los Canos, Cayey, Monserrate, Constancia, Carmen, San Vicente, Alianza.

The crops at Centrals Vannina and Canovanas, also lying in the North Coast climatic zone, but known to be little affected with disease, were:

Year	1916	1917	1918	1919
Vannina	10,464	10,543	12,135	11,733
Canovanas	16,313	14,706	15,413	15,184

The total crops of the island were for these same years:

Year	1916	1917	1918	1919
Tons	483,589	503,081	453,795	406,002

I am informed that there was a small but distinct increase in the acreage reaped from year to year.

(1) That the rainfall on the north coast for the years 1917 and 1918, correlated with the crops of 1918 and 1919, was very deficient and coincided with a reduction in output.

(2) On the other hand, for the same years the rainfall on the west coast was normal and the falling off in yield was similar to that on the north coast.

I discussed this question with Mr. Latimer at Cambalache and he was most decidedly of opinion that though some of the loss was due to the dry weather, yet by far the greater part was due to disease. As a specific instance of this he referred me to certain fields in a small irrigated section, and so without the influence of climate, where the fall in output, due entirely to disease, was very great.

In addition at Centrals Vannina and Canovanas, also within the north coast climatic zone, the crops showed little variation and in the areas tributary to these centrals the disease has not yet become extensive. Complete data as to acreage reaped, etc., which should appear to make the comparison complete, were not available; the inference to be drawn, however, is not invalidated by their absence.

I was also told by Mr. Latimer that much of the decreased output of Cambalache:

Year	1916	1917	1918	1919
Tons	23,443	23,129	15,197	11,021

was due to colonos giving up in despair and leaving their fields uncut. He estimated the difference in tonnage in his worst attacked fields as roughly a reduction from a normal return of 25 tons to one of 17 tons per acre. This proportion is very similar to what Mr. Todd gave me as obtaining in severely infected fields at San German and Anasco and which he ascribed as due solely to disease and not to climatic variation.

It has also been suggested that following on the exaggerated price of raw sugar much land unsuited for cane has been put into cultivation in 1914, 1915, etc., and that the fall in production was in part at least due to the failure of these lands to ratoon properly.

Though without doubt much land that in normal times would not have been planted to cane has been brought into cultivation, I do not think that this planting can be correlated with the fall in production, or in any way connected with the disease. All over Porto Rico wherever I went the disease was just as prevalent in lands known for their fertility as it was in poorer soils. Indeed, it was in the Arecibo Valley, which appealed to me as the finest stretch of cane land that I saw in Porto Rico, that the disease first appeared and where the infection was most severe.

Root Disease and Yellow Stripe.

A suggestion has been made that the yellow stripe is merely a manifestation of root disease, and I looked into this point very carefully.

In Porto Rico areas can very commonly be found in which are stunted canes, and on examination of the basal portion of the stalks there can be found evidence of one or other of the various organisms to which the condition known as root disease is due. While, however, root disease and yellow stripe may be present on one and the same field and on one and the same stool, observation soon showed that the typical lesions symptomatic respectively of yellow stripe and of root disease occurred quite independently of each other and that there was no connection between the two conditions. Indeed, in the form in which yellow stripe occurs in Porto Rico the mottling of the leaf and the eventual appearance of the internodes in cases of severer attack are easily distinguished from the stunted growth and shrivelled dry leaves of such stools as have been attacked by root disease. This appearance on the whole simulates that produced by a severe drouth.

Observations in Tucuman.

In the case of canes attacked by root disease there is, however, often a yellowing of the leaf but the appearance is quite distinct from that due to the yellow stripe. This yellowing has quite recently been studied by Cross in Tucuman, who has shown that the application of soluble nitrogen will restore the vitality of the stool and renew the green color of the leaf. The appearance due to this condition and the effect of soluble nitrogen is thus described by Cross:

"In the Spring of the year 1918–19 there was observed in this province a considerable extension of newly sprouted cane, which, as a result of the attack of root disease, became yellowish, almost white in color, and remained more or

less stationary in its growth until it was able later on to overcome the disease, when it became green again and at the same time renewed its growth. Seeing that the chlorosis of the cane is due to want of nutrition caused by the destruction of many of the roots, it appears logical that the cane could overcome the disease more readily if it were strengthened by applications of soluble nitrogen fertilizer immediately available. To investigate this possibility it was resolved to carry out experiments in two lots of the experiment station containing Zwinga cane which was suffering greatly from the disease in question.

Results of Experiments.

"In the first lot, sulphate of ammonia was applied to certain rows, and Chilean nitrate to others, both of these fertilizers being immediately soluble. Other rows in the same lot were not fertilized. The fertilizer was applied at the rate of 6 kilos to a row of 100 meters, on the 8th of November, that is to say, just at the time the cane was suffering most from the disease. In a few days a considerable improvement took place in the fertilized cane, which recovered completely and took on the deeper green color a long time before the non-fertilized cane."

This experience is in line with that of Mr. Gray at Soledad, and I suggest that possibly there may have been some confusion between the two conditions.

As a further explanation of the results observed by Mr. Gray I would suggest the possibility of a double infection with both root disease and yellow stripe, for in such a case the interpretation of the results obtained from an application of soluble nitrogen would be likely to be very confusing.

Nature and Course of the Disease.

The disease has all the earmarks of being caused by some parasitic micro-organism, though up to the present there has been published no account of any such as associated with the disease. On the day that I left Porto Rico I was, however, asked to see the work that has recently been done by Mr. Metz at the insular station. Mr. Metz showed me preparations indicating that he had isolated in both leaf and stalk, and residing in the interior of the parenchyma, an organism presumably connected with the disease. Mr. Metz gave me leave to refer to this matter in any report that I might make, though, of course, until he makes some statement himself he is in no way committed.

Although the disease is essentially a leaf disease, the presence of the presumptive causal organism in both stalk and leaf may account for certain contradictory experiments that have been made:

(1) In some cases, as at Vista Alegre (Fortuna) a plot planted with seed taken from infected stock came up sound. If here the infection had been confined to the leaves only the anomalous result is accounted for.

An Awkward Question.

(2) Experiments the reverse of the above were shown me, where seed cane apparently healthy gave an infected stand, even from the first. In this case the parasite may have been present in the stalk without the latter showing any out-

ward sign of the disease. I believe that this has occurred in a number of cases, since in many cases it is impossible to determine if a cane is infected or not when once the leaves have been removed. This presumptive evidence of the parasite in the interior of the stalk is then a very awkward feature in the control, since it adds very materially to the difficulty of obtaining sound seed of assured freedom from infection.

What appeared to me, however, as a great difficulty in the control of the disease was the frequency and rapidity of the secondary infection—that is to say, the appearance of the disease in fields planted from sound cane. In many such cases the cane comes up quite sound and continues to do so up to the age of about two months, when the disease appears, not in the oldest leaves, but in those just beginning to unroll. This infection is continuous and progressive, since it is common to see in standing cane many stools with all the lower joints sound but with those in the upper third exhibiting the characteristic symptoms of the disease and with the leaves still attached to the green top heavily infected.

This secondary infection is at times very rapid and from what I gather from Mr. Todd at Guanica it has appeared there so rapidly and extensively as to prevent the rogueing out of infected canes, as has been done so successfully at Fajardo and other places where the disease last appeared and after its nature and danger were understood. A second example of this secondary infection was afforded me by Mr. Latimer, who told me that in the early period of the epidemic the imported seed came from Ponce, where at that time the disease was unknown. Fields at Cambalache planted with this seed came up sound, but rapidly became infected and as diseased as the rest of the district.

Study of Infection Important.

It would appear to be of great importance to study the mechanism by means of which this secondary infection obtains. A lot of work has already been done and at one time insects were suspected of being the carriers, but experiments made to test this hypothesis have up to the present only afforded negative results. Soil infection also seems to have been eliminated, but I hope that the experiments now being carried on by Mr. Metz will soon lead to positive results.

In the worst infected districts it was not uncommon for colonos to abandon their fields and to leave them unreaped. This I consider a most dangerous practice, as these fields can form nothing else than foci of infection to the surrounding areas.

I would also offer as a suggestion that certain phases of the disease seem to point to there being other host plants than the cane, which serve as reservoirs for the parasite whence it may be conveyed by agencies such as the wind to other fields. Such host plants might be wild grasses, growing on the cajones and in nearby pastures. Without such causes it is hard to see how a field plowed under, planted to cow peas, and planted to cane after the peas have been plowed under, could become so rapidly infected as has often been observed at Guanica. That such a means obtains in other plant diseases is well known, and in some cases the presence of a secondary host is essential.

Control of Disease.

A great deal of very painstaking work has already been done to this end, and it has been mainly concerned with seed selection, rogueing out and with the planting of immune varieties or rather with those that are either resistant or tolerant to the disease. These and some other methods are discussed below.

Seed Selection: While it has been definitely shown that the plant of sound seed gives a healthy stand, the presence of secondary infection very much complicates the matter, though in the absence of the latter this would afford a complete control. In certain localities the infection is so wide spread that it is a matter of difficulty to obtain sound seed in quantity or to know that seed apparently sound is not infected. In such a case I would be rather inclined to select by fields (*i. e.,* use for seed cane from those fields known to be least infected) rather than to attempt to select sound seed from the diseased areas. I would also suggest the possibility of establishing seed nurseries in localities remote from the cane areas, provided there is any land available for this purpose. This suggestion will be recognized as borrowed from Java practice, where it was established as a means of controlling the "sereh" disease, and is one that has now become there a matter of routine. Quite possibly it has also unconsciously helped there in anticipating any outbreak of yellow stripe. How such a scheme will be applicable in Porto Rico can be best decided by those familiar with local conditions.

Rogueing: While it has been definitely established that this means will, when properly applied as soon as the infection appears, prevent the spread of the disease, there is so much of Porto Rico now infected that I believe this means can only be used to prevent the spread of the disease in those areas that still remain free. In certain parts rogueing would almost mean the uprooting of the whole planting, and in certain cases I was led to believe that the infection did not go so much from stool to stool as that it was introduced from external sources.

Rotation of Cane Areas.

Decrease of Ratoonage: It has been found that the disease increases the longer the same planting is allowed to occupy the land and therefore at Guanica by this time 75 per cent of the total area is under plant cane. This is, I take it, only a temporary expedient, since under normal conditions such a routine would prove far too expensive.

Intermediate Crops: The system of green soiling with cow peas that is now in common use should certainly afford a means of diminishing the extent of the disease, but even so at Guanica several instances were shown me where fields so treated became heavily infected after planting and after coming up quite sound. While on this subject I cannot help referring to the faultiness of that system of agriculture which maintains continuously on the land but one crop and to this system I am inclined to attribute the frequency with which cane crops have been in times past attacked by epidemics of disease. Under present conditions I cannot suggest any other alternating crop for use in Porto Rico, but the matter is one that should have attention.

THE TREATMENT OF TRASH: I gathered that in Porto Rico cane is never burnt before cutting, and that the trash is always allowed to remain and rot on the fields. As an agricultural practice this system is absolutely correct and the practice of burning off crop residues should be condemned. In some other localities devoted to cane cultivation it is both customary to burn before cutting and to burn off the trash which remains on the fields. It appears to me that there might result a diminution of the disease if such a routine were adopted as a temporary expedient in Porto Rico, especially in those areas that are infected with the disease. Possibly the adoption of this routine has had some effect in protecting the Hawaiian Islands from an epidemic such as has occurred in Porto Rico.

SPRAYING OF CANE SUGGESTED.

SPRAYING: It did not occur to me to discuss this means of fungus control while in Porto Rico, and even now I hesitate to introduce it lest it be thought altogether too impractical. Spraying with bordeaux mixture or with lime sulphur washes is usually only applicable to crops of great intrinsic value, such as fruits and vegetables, and I do not think that it has been applied to extensive areas such as the cane except in one instance. Some years ago the Olaa plantation in Hawaii put into operation a system of arsenical sprays as a means of weed destruction, that plantation being most notoriously infected with weeds and grass. The problem of cheap application was solved by the use of animal-drawn tanks through the fields. The cost of application was found to be 65 cents per acre per plantation, including the cost of the spraying mixture, one man and one mule taking care of from three to five acres per day.

I do not lay much stress on this suggestion and at best it could be applied to young cane only, and as a means of preventing the secondary infection.

It might be objected that as the parasite resides in the interior of the leaf, spraying would necessarily be inoperative. I believe, however, that in the secondary infection the parasite enters from outside and possibly gains access to the interior of the leaf through the stomata. Spraying cane would then be comparable at this stage to spraying as used to prevent the attacks of rusts and other organisms that have their habitat on the exterior surface of the leaf.

PLANTING OF IMMUNE VARIETIES: Without doubt this is the means upon which most reliance should be placed, and in the history of past epidemics it is the one that has proved most successful. Much progress has already been made in Porto Rico in this way, and following on the efforts of Mr. Earle and the observations that have been made at Fajardo and Guanica experiment stations, the most tolerant and resistant varieties available are now known and are being extended. Of the newer varieties D 117, D 433, G. C. 701, G. C. 1313, and G. C. 1486 appear to be much more resistant than are the Rayada, Crystalina and Yellow Caledonia that formed the bulk of the cultivation before. D 443 at present exists only in quantity at Fajardo, but it appeared to me to be a cane of great potential value. To these ought to be added Java canes J 56 and J 234, which seem to have been responsible for the introduction of the disease, but which are themselves resistant to it. (On this point compare the introduction of measles by Caucasians to the Hawaiian Islands, where amongst the natives it created a pestilence.)

KAVENGIRE CANE IMMUNE.

The cane to which very much interest is to be attached is that known as Kavengire and which should be called Uba. This cane is certainly immune. Experiment has shown that it gives a very high tonnage and a juice about equal to that afforded by Yellow Caledonia. It is, however, a cane dissimilar in habit from other varieties and one likely to arouse prejudice. It has a high percentage of fibre and its stalk is covered with an excessive quantity of wax. Its juices are hard to defecate and because of the wax trouble arises at the filter press station.

This cane is, however, the only one extensively grown in Natal, where the production is now over 100,000 tons of sugar per annum, and so it cannot be regarded as an experimental one. A very full discussion of this variety appears in the Louisiana Planter of December 20, 1919, and to the analysis there quoted I would add that they refer to sub-tropical cane and that probably in the tropics there would be considerably more sugar than here indicated.

I am of the opinion that an extended trial should be given to this cane in those areas that are heavily infected with disease. After the disease is under control return would be made to the older varieties. [W. P. A.]

Agricultural Progress in Louisiana.*

At the meeting of the Louisiana Sugar Planters' Association, on March 10, 1920, a committee on "Agricultural Progress" reported on different phases of the sugar industry in Louisiana. The following extracts from this report summarize points of special interest.

FERTILIZATION OF CANE.

The application of fertilizers was greatly delayed, and with few exceptions fertilizers were not applied until the early part of June. The exorbitant prices and scarcity of commercial fertilizers prevented planters from making their usual applications. Tankage, bat guano and cotton seed meal were the most popular fertilizers used. In the parishes along the coast, shrimp dust and fish scraps were used by some of the planters, and from the results obtained, they class this material on a par with cotton seed meal. At first these refuse products were about the cheapest fertilizers on the market, but the growing demand has increased the price.

The reports obtained from plantations using tankage and bat guano show that very little good was derived by the cane crop from these fertilizers last year. On Catherine plantation in Iberville, Mr. Supple reports excellent results from mixtures of cotton seed meal and acid phosphate. A mixture of 200 pounds each per acre was used on stubble cane.

*The Louisiana Planter, March 20, 1920.

The application of filter-press cake was conducted throughout the sugar district. Planters are convinced of the value of this material as a fertilizer, and are taking time to apply it to their lands. There are many instances where lands that produced 20 tons per acre, produced 30 and 35 tons per acre after a liberal application of filter-press cake. It also has the same effect on corn, increasing the number of bushels per acre. The filter-press cake increases the fertility of the land for at least two or three years.

The use of stable manure is increasing every year, and efforts are being made to construct proper manure sheds and pits to collect the manure. The small planters are ahead of the large planters in the use of stable manure. As a rule the former take great pains to save all of the manure, and will oftentimes go to the trouble of buying manure from stables in neighboring towns. This manure is carefully applied to crops of cane and corn. Some of the large planters have purchased manure spreaders and are applying more manure than in former years.

In the Parish of Lafayette, Mr. Eug. Landry conducted a field test on sugar cane using stable manure. Two plots side by side were selected for the purpose, with uniform land and stand and both receiving the same preparation and cultivation. On one plot manure was applied at the rate of two tons per acre and the other plot was left without manure or fertilizer. The plot that received the manure gave an increase of 4.2 tons of sugar cane per acre.

The general practice in the sugar district in the application of fertilizers, is to fertililze only the plant cane. As a rule the land of the plant cane crop has been in peas, and has either received all of the crop or one-third of the crop as green manure. This gives a sufficient amount of nitrogen to easily take care of a good crop of cane. However, while the peas enrich the soil in nitrogen, no phosphoric acid is added, and as phosphorus is one of the essential plant food elements, cane crops on such lands, while they yield heavy tonnages generally, produce juices that are a little low in sucrose. On the Raceland properties in Lafourche, straight applications of acid phosphate at the rate of 200 pounds per acre to plant cane have improved the sucrose yield of plant cane crops.

In the fertilizer tests that were conducted for the Colonial Sugar Company and the Longview Sugar Company, comparisons were made between different fertilizers. Mixtures of nitrate of soda and acid phosphate gave a net profit of \$91.14 per acre; nitrate of soda applied alone gave as high as \$97.67 per acre; while tankage gave a net gain of \$11.75 per acre. In another test a mixture of 254 pounds of nitrate of soda and 254 pounds of acid phosphate produced 8.3 tons per acre more than the unfertilized field, giving a net gain of \$110.27 per acre.

Where comparisons were made between cotton seed meal and acid phosphate and nitrate of soda phosphate, the following results were obtained:

Plot No.	Fertilizer per acre	Increase over check	Net gain per acre
1	300 lbs. cotton seed meal 225 lbs. acid phosphate	2.5 tons	$ 25.08
2	100 lbs. nitrate of soda 100 lbs. acid phosphate 200 lbs. cotton seed meal	5.31 tons	67.61
3	200 lbs. nitrate of soda 225 lbs. acid phosphate	3.52 tons	41.17
4	200 lbs. nitrate of soda 450 lbs. acid phosphate	4.14 tons	47.75
5	300 lbs. nitrate of soda	8.30 tons	111.76
6	100 lbs. nitrate of soda 200 lbs. acid phosphate 160 lbs. cotton seed meal	4.00 tons	47.97
7	100 lbs. nitrate of soda 225 lbs. acid phosphate	3.06 tons	38.45

In Lafayette Parish fertilizer tests were conducted with fertilizers as follows:

(a) Mixture containing 25 lbs. nitrogen and 36 lbs. phosphoric acid, per acre.

(b) Mixture containing 25 lbs. of nitrogen and 76 lbs. phosphoric acid, per acre.

(c) 300 lbs. and 10 tankage per acre.*

(a) gave net gain of $108.06 per acre.
(b) gave net gain of 91.26 per acre.
(c) gave net gain of 80.27 per acre.

Mixture (a) is the one recommended by the Sugar Experiment Station, which for the past four years has been giving excellent results at the station.

LAND IMPROVEMENT AND SOIL FERTILITY.

During the past year, even with the bad conditions, there was quite a lot of interest displayed in the sugar district for improved methods. The questions of land improvement and soil fertility are receiving more attention. The old three-year rotation system which was so universally used is now gradually going out. The four-year rotation, which is replacing this system, showed up exceedingly well in the Parish of St. Mary, on the Burguieres plantations. This group of plantations, taking into consideration the year, produced fairly good crops of cane and corn; while neighboring plantations in the same section, using the old three-year rotation, made very poor crops.

The cow pea is gaining more and more ground as a green manure. The old system of pulling all of the vine for hay is being discontinued. A large number of planters are turning under all of the vines and growing their hay crops on

*Evident misprint. Meaning not clear.—(Editor).

lands unsuitable for cane, such as heavy black lands, headlands, lanes and levees. On Uncle Sam plantation, in St. James, all of the hay required for mules on the plantation was grown on 27 acres of land planted in alfalfa and 70 acres in red clover. This is giving more than enough hay for the mules, and Mr. Jacobs is so well satisfied that he has adopted the system entirely and is now plowing under all of the crops of pea vines. On the Godchaux properties, in Lafourche, all of the hay crops are produced on levees and lanes, and all pea vines are turned under. The same system is also in use on Southdown, in Terrebonne.

Cover crops of sour clover and red clover were planted on fall plant cane in the Parishes of West Baton Rouge, St. James, and Lafourche. This is a procedure that originated at the Sugar Experiment Station and is giving excellent results there. So far it is only being tried by a few of the planters of the State. However, the results attained at the Sugar Experiment Station justify a more extended use. The results show as high as four tons per acre increase in stubble cane the following year on plots where the clover is turned under, over plots where no clover crops are used.

Velvet beans are being used to a great extent on heavy lands. The heavy dense growth of vines and leaves is plowed under in the fall with disc plows. Reports received show that this treatment makes the black lands easier to work and more productive.

Varieties of Cane.

The year 1919 was a very poor year for proving out the good qualities of improved sugar cane varieties. In a good many cases the purple, ribbon, and LaPice canes gave higher tonnages than the seedling varieties. The D 74 variety, which is the favorite cane in the alluvial sections, due to adverse weather conditions and lack of proper cultivation, did not produce its usual good yields. However, in certain favored sections, where there was less rainfall and a little more sunshine, which allowed for better cultivation, some fairly good tonnages were obtained. This clearly proves that this variety of cane must have the proper treatment in order to produce maximum returns, and, unlike the home canes, it is unable to adapt itself to adverse conditions.

The variety D 95 is being discarded by the majority of the planters. In the Parish of St. John, San Francisco plantation still plants a large acreage of this cane, and, due to its high sucrose content, it is still being retained on this plantation. Good results are also reported with D 95 in Plaquemines Parish, on Myrtle Grove plantation. Fully half of the properties are planted in this variety of cane and it is giving splendid results. The lands in this section are extremely rich and can take care of the food requirements of this variety of cane. The chief objection that planters have against D 95 is that it is too hard on the land, and the seed cane is harder to keep than the other canes.

The superiority of D 74 over home canes is still unsettled in certain localities of the State. The most successful planters of the State are planting D 74, and wherever the proper system is being used it is giving better results than the home canes. Mr. Robert, a successful planter in Iberville, claims that poor crops of D 74 stubble are the results of shallow shaving in the spring. He says, further, that if the cane is shaved deep and followed by good cultivation and fertilization

a good crop will result. In the extreme upper part of the sugar district, D 74 is giving better results than home canes when given a fair trial. On Mr. F. C. Swann's plantation, near Cheneyville, D 74 is giving more tons per acre than purple cane. Trials conducted on Inglewood plantation, near Alexandria, also proved D 74 to be superior to purple cane.

The Louisiana seedling No. 511 is still the most promising of the Louisiana seedling canes. On one plantation, Oaklawn, in St. Mary, it has been extended over an acreage of about twenty-five acres. This variety is still producing about 4 per cent more sucrose than D 74. Louisiana seedling No. 253 is the next in importance. This variety has been extended to the extent of about fifteen acres on one plantation and twenty-five acres on another. The percentage of sucrose in this cane is not very high, but on the other hand it produces a heavy tonnage.

Sugar Cane Insects.

The moth stalk borer is still the most serious sugar cane insect pest. It is quite noticeable that in sections where fall planting is practiced on a large scale, the borers are not present in such large numbers. In sections where most of the planting is done in the spring, the borers are much more numerous and do more damage to the cane.

The non-burning of cane trash on lands that were prepared for corn was followed out by a large number of planters. On stubble cane, however, this method is considered impracticable by the majority of the planters.

Mr. E. R. Barber, of the United States Department of Agriculture, made another trip to Cuba, to continue the work of collecting cane-borer parasites. The parasites (tachinid flies) were received by Mr. T. E. Holloway at the Sugar Experiment Station and placed in cages especially prepared to receive them. Later on 180 parasites were liberated on three plantations in the State, located in the Parishes of Iberia, Iberville, and Lafourche. Mr. Holloway stated that there were not enough parasites to distribute to all of the plantations, and as there was more chance of the parasites dying out if split up in very small lots, he selected the above mentioned three central points. Investigations made several times after the pararsites were liberated showed that they were multiplying and destroying borers.

The mealy bug was found to be doing considerable damage in different sections of the cane district. This insect interferes with the proper development of the cane; decreasing the tonnage and injuring the eyes of seed cane to such an extent as to prevent proper germination. Poor stands of spring plant cane are often due to the attacks of mealy bugs. The planting of fall cane has been found preferable to spring planting in heavily infected sections. It seems that cane in the windrow provides a good place for mealy bugs to pass the winter, where they work on the cane to some extent and are in good shape for the next crop. In fall plant cane the insects are covered with soil, and as they remain in this condition, large numbers are killed out.

The Argentine ants are directly responsible for the mealy bug attacks on cane, for they foster the mealy bugs, carry them around from place to place, and help and attend them in many different ways. The ants are always found with the mealy bugs, and if the latter are plentiful it is a certain thing that there will

be hordes of ants. At the Sugar Experiment Station excellent results are obtained in controlling the mealy bugs by fighting the Argentine ants. This was accomplished by setting out cans of Government ant poison in the field. The ants were attracted by the poison and destroyed in large numbers. After a few months' time practically no ants and very few mealy bugs were found in the field, which previous to the application of the ant poison was heavily infected with both insects.

The rough-headed corn stalk beetle is another insect that occasioned some trouble in some of the Parishes, causing serious damages to stands of cane and corn. In some cases the beetles completely destroyed stands of corn and cane. The beetles feed on organic matter, and make their appearance in early spring —staying around the roots of the plants, feeding on the young, tender shoots and severing them from the mother plant. One of the most effective measures tried out was the use of nitrogenous fertilizers early in the season, which produced a quick growth and helped the plant to overcome the attacks of the beetle.

Sugar Cane Diseases.

A complete tour of the sugar district revealed that the sugar cane root disease is quite common all over the State. The amount of injury caused by this disease depends entirely upon the cultivation and attention given to the cane. In some of the fields of stubble, where the cane was neglected, the cane had succumbed completely to the disease—producing weak, spindling stalks and a resulting low tonnage. In a good many instances the stubble was so poor that it was really unfit for the mill, and as a last resort such cane was taken for seed purposes. This is a very poor practice and expensive in the long run, for such cane is bound to be heavily infected with the disease; and as the procedure is repeated year after year the disease will become more strongly established and will actually lower the yields on the plantation.

The new sugar cane mosaic disease which was found to occur in various parts of the sugar district is causing widespread attention among the planters. A complete survey of the sugar parishes was made during the summer by a staff of Government pathologists, for determining the exact whereabouts of the new disease. A complete report of information and recommendations for the mosaic disease has been issued by the Department of Agriculture.

The mosaic disease occurred in the home canes—purple, ribbon, and LaPice, D 74, D 95, L 511, L 253, and L 231. It was found to be more generally spread in the D 74 than in the other varieties. However, the D 74 in some instances was found to be absolutely free of the disease. In the Parish of Lafayette, where only the purple cane is grown, the fields were free of mosaic disease. The same condition exists in the Parishes of Rapides and Avoyelles. In the latter two D 74 is grown to some extent and it was found to be free of the disease. The mosaic disease was found in both well ctultivated fields and in poorly cultivated fields, also in the best cane and on the best lands.

The following recommendations were advocated:

To plant healthy seed cane and discard all seed cane infected with the disease.

To plow up mosaic-infected stubble, after harvesting the cane.

To plant the more resistant varieties.

On one plantation, where 50 per cent infections were found in practically

all of the fields, special seed plots of healthy cane obtained from neighbors have been started up. The plots have been planted a good distance away from infected fields, so there will be less likelihood of the disease passing to this cane. Outside of this attempt there has been no further efforts reported where control methods are being used. The mosaic disease, while it has very probably been in Louisiana a number of years, is relatively new, and a complete study has to be made to determine the exact harm that it is doing to the cane crops of this State. In the meantime the planters should take proper precautions, learn to know the disease, and endeavor to plant healthy seed and get rid of cane infected with the disease.

TRACTORS.

In spite of all of the hard and strenuous conditions of last year, the tractors made a considerable amount of progress in the sugar district. Various types of tractors were used, including two wheels, four wheels, and caterpillar tractors. In the breaking of land the four-wheel tractors were used to a greater extent than the other two types of tractors, which were used more for cultivation operations. On lands worked by the Murrell Planting Company and Cinclare all of the lands planted in fall cane were prepared with tractors. Tractors were also worked to a large extent in the Parishes of Lafourche, Terrebonne, Assumption, Ascension, Iberia, St. James, St. John, and Avoyelles.

The following is an example of some interesting tractor work on Cinclare:

Bursting out middles in corn and cane.

One tractor did the work of three four-mule teams and implements per day.

Cost of tractor work, per acre, 24c.

Cost of same work using mule teams and implements, 73c per acre. In making this calculation the time of the men and the mule feed consumed in one day was figured at 60c per head.

In the tractor cost the time of the operator and the gasoline and oil consumed during the day were taken into consideration.

In the Parish of Jefferson, Parish Agent L. W. Wilkinson reports an interesting comparison made on Willswood plantation. In destroying stubble one tractor and two men did the work of 22 mules and 10 men. The cost of tractor and implements was $1,900; of the 22 mules, $8,000.

In Lafourche Parish Mr. Roper reports that cane was cultivated and laid by with tractors. On some of the other plantations tractors were used for a few cultivations, and when the cane was too high the crop was laid by with mule teams. [J. A. V.]

Insects Injurious to the Algaroba Feed Industry.

By John Colburn Bridwell.*

The following paper is substantially a report submitted to Mr. F. W. Macfarlane, president of the Union Feed Company of Honolulu, by which company the writer was employed from November 20, 1919, until February 1, 1920, to continue investigations of the algaroba weevils previously undertaken by him.

The work upon the algaroba weevils was then taken up by the Bureau of Entomology, with the writer in charge, and he has since been authorized to proceed to California, Arizona, New Mexico, and Texas, to study the natural enemies of these weevils there. Mr. H. F. Willard of the Bureau of Entomology is associated with him in the local end of this work.

It is appropriate now, when plans are being made to combat the weevils attacking the algaroba beans, to bring together a summary of our present knowledge of the insects involved, to indicate methods of work looking toward the prevention of future injuries, and to point out some additional lines of investigation necessary to give us the knowledge by which we may check up accurately upon the results of our remedial work.

Insects Effecting Injuries to the Algaroba Pods. There are four insects now effecting perceptible injury to the algaroba industry. These are three bean weevils which begin to infest the beans in the field: the Algaroba or Mesquite Weevil,[1] the Glue-bush Weevil,[2] and the Tamarind Weevil,[3] and a moth, the Indian-meal Moth,[4] which feeds in the pods during storage. The bean weevils feed principally upon the beans themselves, while the moth confines its feeding to the sugary contents of the pod outside the beans. The common bean weevil has been reported as attacking the algaroba, but this was due to an error of identification of the insect at work.

The Algaroba Weevil. This weevil is a native of the southwestern United States, Mexico, and, apparently, also of South America, where it attacks the seeds of the mesquites of various species and of the screw bean. It is not known to attack other host-plants there, and here it confines its attacks to the algaroba, as far as my observations have gone. While it has been reported to attack the pigeon-pea in Hawaii, I believe this record is based upon an error of observation.

This species lays its eggs singly or in small masses of from 2 to 7 or more upon the edges of the very young pods, often before they are more than an inch or two in length. When the first egg hatches from a mass, the young larva or grub begins at once to penetrate into the young pod and a copious flow of gum usually starts up from the wound made by it in feeding, and this frequently dislodges the egg-mass before others of the hatching larvae have had time to enter the pod, or it may cover the mass so as to drown them.

*U. S. Bureau of Entomology.
1 **Bruchus prosopis** Leconte.
2 **Bruchus sallaei** Sharp.
3 **Caryoborus gonagra** (Fabricius).
4 **Plodia interpunctella** (Huebner).

The young grub entering makes an open wound in the rapidly developing pod, which, even as small as it is, permits the entrance of bacteria and molds, and the disturbance set up by them frequently causes the death of the embryo-seed opposite to it and results in the deformation of the pod at this point.

The young grub, after it has entered, feeds for some time between the two fibrous layers of the pod in the position where the sugary, pithy layer develops later. At this time this layer is extremely fluid and the grub is bathed in liquid. It makes its way about in a tiny thread-like tunnel, and when it is ready to enter the young seed has often reached a place opposite a different bean from the one near which it entered. It is not until the young beans have reached nearly full size and the seed-leaves are dark green and of a firm consistency that it enters the seed and makes its way to near the center of one of the seed-leaves and begins to feed. Upon the rich food of the seed-leaves it develops rapidly and by the time the pod has reached full length and breadth, but before it has become nearly so thick as it is when ripe, the grub reaches its full size and changes into the form of the adult weevil, or, as we say, it pupates. The pupa which is formed resembles the adult in form, but is white and very soft and delicate, and would be easily crushed if not protected by the seed and pod. It is while the weevil is in the grub stage near its full size, or in the pupa stage, that it is attacked by one class of parasites. It is encouraging to learn that the pod is then still green, it has not yet reached its full thickness, and its substance has not yet hardened so as to prevent the pararsites reaching the weevils with their stings and placing their eggs upon them.

By the time the weevils have changed from the pupa to the adult and are ready to emerge, the pods have usually reached full size and ripened and fallen to the ground, though a few of the weevils emerge just as the pods are changing color on the trees. The weevils are, then, just about to emerge from the pods when the crop is harvested and brought into storage. Certainly most of them emerge before the beans have been in storage more than a week or two. The question naturally arises: Can these emerging weevils cause an infestation of the dry pods? Here experiment in the laboratory and observation in the warehouse seem to contradict each other.

In the laboratory it is easy to secure egg-laying in the dry pods if there are openings in the pods for the insertion of the eggs, for the weevils do not seem to lay them upon the surface of the ripe pods, probably because the young grubs are unable to make their way through dry outer layers of the pod. From such dry pods adults have been bred, emerging in one case one hundred and thirty days after the eggs were laid. But in the storerooms observations made in November and December, after the beans had been in storage for more than two months, show no certain indication of reinfestation of the dry pods, and I am firmly convinced that under such conditions as these observations were made, when the weather had continued hot and dry during the period of storage, so that the pods had become very dry and hard, little or no breeding was going on. However, it is probable that considerable reinfestation of ripe beans takes place when beans are left out in the open and moistened by the rain and dew, and it is not improbable that if long-continued damp weather occurs while the beans are

in storage they may absorb enough moisture from the air to permit the weevils to breed in them even in the warehouse.

The algaroba weevil, like the other species of bean weevils, is unable to breed in the ground algaroba feed, whether pure or mixed with other feeds.

The Glue-bush Weevil. This weevil closely resembles the algaroba weevil, and when it attacks the algaroba seems to affect it nearly in the same way, but it also attacks the seeds of the glue-bush,[1] and, since it is known to attack other seeds in the Southwest and Mexico, where it occurs as a native, it may also be found to affect other similar seeds here. It was first found on Punchbowl in May, 1918, and was then apparently confined to that vicinity, but since that time it has extended its range from Koko Head to Kaena Point. It was first found here attacking the seeds of the glue-bush, which seem to form its principal food in its native home, but was soon bred experimentally from dry algaroba pods, and it was recently found to constitute 27% of a small lot of weevils bred from algaroba pods at Waikiki by Mr. C. E. Pemberton. Out of about 3,000 weevils picked up dead in the Union Feed Company's warehouse, about 1% were of this species. We can only conjecture whether it will become a pest of first importance in the algaroba beans or if it may not after a time confine itself more closely to the glue-bush.[2]

The Tamarind Weevil. This weevil is usually much larger than the other two. Its eggs are considerably larger and are laid scattered singly over the pods of the plants which it infests. It also attacks the seeds of the tamarind, as its name suggests, and it may have been brought in these seeds from India, which is its native home. It also breeds in the seeds of the golden shower, pink shower, pink-and-white shower, two species of *Bauhinia,* the glue-bush, and other leguminous shrubs and trees.

Its attacks upon the algaroba differ from the other two bean weevils in two important ways. First, a single grub rarely finds enough food in a single bean, but devours two or three before it reaches full growth, and, second, the eggs are usually laid after the pods are ripe, so that the eggs are just hatched or hatching when the beans are brought into storage, and consequently practically all the damage done by it occurs after the beans are in the warehouse.

The Damage Done by the Various Weevils. We have no data sufficient to enable us to estimate the amount of damage done by the weevils, but observation makes it apparent that the losses are very serious. In one small lot examined, which was obviously much less infested than many of the beans brought in during the present season, 25% of the beans were eaten or missing, and in my judgment practically all this loss was due to the weevils. It will require considerable further work to secure data upon which to base any accurate estimate of the losses and to divide it between the two weevils whose work is done at the beginning of storage and the one doing its work in storage, but as a rough guess I should say that perhaps two or even three times as much damage is done before as after storage. It is important that such data should be collected, so that we can check up on the results of any work undertaken.

Parasites of the Bean Weevils in Hawaii. Two species of parasites are

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[1] Acacia (Vachelia) farnesiana.

[2] More recent observations seem to indicate that this species will prove to be even a worse enemy than the algaroba weevil.

doing considerable beneficial work in checking the multiplication of the Algaroba weevil and the Glue-bush weevil in Hawaii, and one of them is doing even better work against the Tamarind weevil. The first of these is an egg parasite, *Uscana semifumipennis* Girault, attacking all the species, and a larval parasite, *Heterospilus prosopidis* Viereck, which is not yet known to attack the Tamarind weevil.

The Egg-Parasite, Uscana. This is an exceedingly small, four-winged fly, barely visible to the naked eye, which by means of its sting or ovipositor bores a minute hole into the egg of a bean weevil and inserts its own egg within. From this a minute grub emerges and feeds upon the contents of the weevil egg and in due time produces a fly like its parent, so that the weevil egg, instead of producing a grub to feed in the seed, gives forth a fly to attack other eggs.

The algaroba weevil and the glue-bush weevil, as has been said before, lay their eggs usually in masses of from two to seven or more. In the masses where more than two eggs are present one or more eggs are so overlaid by the others that the parasite is not able to reach it, and thus, even if part of the eggs are parasitized, one is likely to escape and produce a grub. For this reason the tamarind weevil, which lays its eggs scattered, is more heavily parasitized than the others, and all the lots of eggs examined recently show that from 70–90% of the eggs are destroyed, but even in the case of the others it is probable that from 60-70% are usually attacked.

This parasite has been known for about ten years in the Islands, and it is probable that we are deriving all the benefits from it which it is capable of affording

The Larval Parasite, Heterospilus. This is a reddish, four-winged fly, considerably smaller than a housefly, which has the power of finding the grubs of the weevils in the pods or seeds and boring with its ovipositor down through the pod, stinging and placing its egg upon the body of the grub. From this egg the grub of the pararsite develops and feeds upon the weevil grub, which has been paralyzed by the sting. In due time the adult parasite emerges from the pod through a hole much like that made by the weevil in emerging. The parasite seems to be very irregular in the extent to which it attacks the weevil grubs, but in some cases it appears to do considerable good. This pararsite was introduced about ten years ago by the Federal Experiment Station, and it is probable that it is by this time doing as effective work as it will ever do.

The Attacks of the Indian-meal Moth. This is a small moth which, as its name implies, commonly attacks corn meal, though it is not the most common moth doing such damage in the Islands. It is known to attack many kinds of stored foods and feeds. It is at present breeding in considerable numbers in the algaroba warehouse.

The eggs are laid by the moths on the bags in which the beans are stored, and the young caterpillars hatching from them find their way into the bag and enter preferably broken pods, where they feed upon the sugary pith. After reaching full growth the caterpillars leave the pods and crawl about in search for a place to change into the adult moth. This they usually find on the surface of the bag where it touches another bag or in other crevices about the warehouse. Here the caterpillar spins a loose silken cocoon and shortens up, becomes inactive and sheds its skin to disclose the brown pupa. While the caterpillars are

crawling about in search of hiding places for the cocoons they are subject to the attacks of their enemies, of which three have been observed at work in the warehouse. These are the red fire ants, which devour them bodily; a small bug, which pierces the skin and sucks out the juices from their bodies; and a common parasite of moths in stored food products, which first stings the caterpillar and then deposits its own eggs upon it, and the grubs hatching from these eggs devour the caterpillar and develop into the parent form, several grubs feeding on a caterpillar.

It is not easy to estimate the amount of damage done by this moth, and the only remedial measure I should at present suggest is to subject the bags in which the beans have been stored to some sterilizing process, either heating them in the drier or fumigating them. This is suggested because the caterpillars or pupae are frequently sent out with the bags and are often not destroyed in handling, and thus serve to infest the new beans, probably sooner than they would be otherwise. Indeed, this would be advisable as a general practice with all bags as they are emptied, so as to destroy any vermin they may contain.

Remedial Measures Against the Weevils. The remedial measures which seem advisable may be considered under two heads, according to their being directed against the weevils in the warehouse or in the field. Work in both lines seems called for, since the bulk of the injury done by the tamarind weevil and the meal moth is done after the beans are in storage, and many of the other weevils which are in the pods at the beginning of storage now escape which might be killed then and retained to contribute to the nitrogen contents of the feed. Such measures would also tend to insure the beans against any reinfestation which may take place under special conditions. It must not be considered, however, that this treatment will in any way change the beans so that reinfestation cannot take place from outside. It is only that all the weevils in the bags should be killed at the time the beans enter storage. On the other hand, the bulk of the damage done to the beans by the algaroba weevil and the glue-bush weevil is done before the beans are brought into the warehouse.

Remedial Measures in the Warehouse. Two methods of killing the weevils in the pods naturally suggest themselves. If it were possible to subject the beans at once to the regular process of drying, so that they were at once heated through to a temperature of from 120° to 140° F., the weevils would be killed by the treatment. But since, as I have been informed, the natural drying of the beans for three months or more in the warehouse effects so great an economy of fuel as to make this storage a practical necessity, particularly as other conditions of the harvest and the plant also forbid the employment of this procedure except under special conditions, we need not consider this idea further.

There remains, then, fumigation of the beans as they enter the warehouse. It might seem that this could be done in the warehouse itself, but all recent investigations of fumigation show that the adaptation of such buildings to fumigation is not practical, since it is not possible to make such a building tight enough to insure success in the operation. With this in view, it is probably best to consider only fumigation in a plant specially constructed for the purpose. There is a set of fumigating rooms maintained in Honolulu for public use by the Territorial Board of Agriculture and Forestry, under the direction of Mr. E. M.

Ehrhorn, which is available for anyone to use if he supplies the chemicals and labor necessary, but it would not seem to be practical for any company handling large quantities of beans. Such firms would need to have their own fumigating rooms. This plant, I am informed, cost about $2,700, and, allowing for construction on a somewhat modified plan, a plant adequate for handling up to 500 bags a day might have been constructed for about the same amount of money at the time when this was built, but at present I believe the cost of construction would be considerably higher. So far as I understand the conditions of the incoming crop of beans, as handled by any firm at present, it would seem that two rooms, each with a capacity of a thousand bags, should handle them as they come in. One side could be filled and fumigated and the other used to receive the incoming beans while the charge in the first operates. Ordinarily 48 hours is considered desirable, though experience may show that less time will serve in a tight cement building. Such a plant would also handle other fumigation required in other lines of business as well.

Measures Against the Weevils in the Fields. Whatever good results are secured by the fumigation of the beans at the time of bringing them into storage. the larger amount of damage done by the algaroba weevil and the glue-bush weevil will remain. There seems to be no other means of reaching this injury besides the importation of the natural enemies of these insects.

Both the weevils in question are natives of the southwestern United States and adjoining Mexico, and it is natural that we should first look to these regions for such enemies. There are several such already known from there attacking both species of weevils. These were made known as the result of some work by the Federal Bureau of Entomology upon the parasites of the cotton boll weevil about twelve years ago, and the bean weevils were investigated only incidentally and principally in the cotton belt of Texas, and it is probable that an investigation of the parasites of the algaroba and glue-bush weevils over the wider extent of the range of the screw-bean and mesquite would result in the discovery of many other important enemies there.

While it is impossible to forecast the results of such work or to plan it very definitely in advance, it may be desirable to discuss the general ideas in mind regarding such work.

The enemies under consideration fall into three classes: egg-parasites, larval and pupal parasites, and enemies of the adults.

Egg-Parasites. The egg-parasite at present found in the Islands is doing such good work that we can hardly expect any improvement from any insect working in the same way. However, in the case of some other insects which lay their eggs in masses as these weevils do, there are parasites which have grubs which, instead of confining their feeding to a single egg, as this one does, pass from one egg to another. If such a parasite could be found for the weevils this would of course be very desirable, but since our parasite seems to be the only egg-parasite of such weevils at present known, we can only hope to find a better.

Larval and Pupal Parasites. Of the larval parasites several are known which attack the grubs and pupae in the pods, and it is quite possible that some of these may be much more effective than the one now present in the Islands. As it is, but very little is known about their manner of life, and it seems of ut-

most importance to secure as many different ones of these as possible and study their habits. There is every probability that the greater number of species of these which are present, the greater the actual number of weevils destroyed will be, since each species is likely to have some little peculiarity of habit which will enable it to attack some individuals which have escaped the others.

Enemies of Adult Weevils. Regarding enemies of the adults, there is but one group which seems to me likely to give useful results. This is a group of digging wasps of the genus *Cerceris.* To avoid any misunderstanding, I may say to begin with that, as the entomologist uses the term wasp, he includes many insects very much unlike the stinging social wasps ordinarily thought of when the term is used. These wasps do not sting and can be handled with impunity. The wasps referred to belong in a general way to the same group as the *Scolia,* which has done so good work against the *Anomala* and the Japanese beetle, and the less well known *Dolichurus,* which has been introduced from the Philippines and has greatly reduced the numbers of a small cockroach found in the mountains here. The wasps of the genus *Cerceris,* many of them, capture adult beetles and bury them in the ground or place them in cells in hollow twigs, and thus provide them for food for their grubs. Each species usually selects beetles of a particular group for its prey and largely confines itself to that group. While no American species is known to attack the group of weevils to which the pests we have under consideration belong, at least three European species do so, and it is quite likely that when the species from the regions where our pests are native are studied some of them will be found capable of using them and can be successfully introduced into the Islands. If such should prove to be the case, we have every reason to hope from the experience we have had with the *Scolia* and the *Dolichurus* that they will prove effective in the control of the weevils.

The Relative Availability of Nitrate Nitrogen and Commercial Organic Nitrogen.*

By A. W. Blair.

The question of the availability of nitrogenous fertilizers is one of great importance to the farmer. He desires a material that will be sufficiently available to benefit the immediate crop and at the same time he wishes to guard against undue loss of plant food through leaching.

It is a matter of perhaps equal importance to the fertilizer manufacturer, since he wishes to sell the farmer a fertilizer that will give results, and also to use all the available by-products that may be worked into fertilizers.

Since nitrates are readily soluble in water and are assimilated directly by plants, they are considered readily or immediately available materials. Organic

*The American Fertilizer, Vol. 52, March 13, 1920. Reprinted from the Journal of Industrial and Engineering Chemistry.

nitrogenous materials must undergo decomposition in order that the nitrogen may be converted into ammonia and nitrates, and are therefore considered less readily available than nitrates. If, however, we allow sufficient time for their decomposition, will they not give as good results as the nitrates; that is, does the greater residual effect of the organic matter balance the ready availability of the nitrates? In other words, taking results covering a period of years, is a pound of nitrogen in the form of organic matter as effective as a pound of nitrate nitrogen?

For more than twenty years the New Jersey Experiment Station has been making a study of the availability of different nitrogenous materials and the results of much of this work have been published. It seems worth while, at this time, however, to summarize briefly certain phases of this work, and to include new material which has not yet been published. In much of this work the comparison was confined to a nitrate and an organic compound, and on this account this discussion will be confined to results obtained with nitrates and organic materials. The work has been carried on by means of field, cylinder, and pot experiments. The pot experiments constitute a minor part and need not be reported here.

Cylinder Experiments—Series A

The work that has been carried on in these cylinders was originally outlined under the rather broad heading "Investigations Relative to the Use of Nitrogenous Fertilizers," and includes other phases of the nitrogen question than the one immediately under discussion. The soil is a loam (Penn Loam) and has a depth in the cylinder of about 8 inches. This top soil rests on a sub-soil, the whole having a depth of about 45 inches. Lime and mineral fertilizers (acid phosphate and muriate of potash) have been applied regularly, and thus, as far as possible, nitrogen is made the limiting factor.

One cylinder receives no nitrogen and thus becomes the check; one receives nitrate of soda at the rate of 320 pounds per acre, and one receives dried blood equivalent to the nitrate.

A five-year rotation is practiced on these cylinders, and the results are now available from four such rotations, giving a continuous 20-year record. The rotation consists of a year of corn, two years of oats, one year of wheat, and one of timothy. Fertilizers are applied for each of these main crops. A residual crop of corn follows each oat crop, but no additional fertilizer is applied for the corn.

A careful record is kept of the amount of nitrogen applied to each cylinder and also of the amount of dry matter harvested and the nitrogen removed by the crops. Wheat is harvested at maturity and saved as grain and straw. All other crops are harvested as hay or forage and reported as dry matter. In the accompanying table, grain is included in total dry matter.

The average yield of dry matter and the percentage of nitrogen recovered for the twenty years are summarized by ten-year periods in Table I.

TABLE I

Treatment	Grams Dry Matter per Cylinder		Per Cent Nitrogen Recovered	
	1st 10 Yrs.	2d 10 Yrs.	1st 10 Yrs	2d 10 Yrs.
Nitrate of soda	237	243	60.48	64.35
Dried blood	207	185	39.90	37.48

From these figures it will be observed that the nitrate has given larger yields and a higher nitrogen recovery than the blood. The nitrate shows an average nitrogen recovery of 62.4 per cent, while the dried blood shows a recovery of 38.7 per cent. Furthermore, the yield with nitrate is slightly higher for the second 10-year period than for the first, while the reverse is true for the dried blood.

Taking the 20-year average, the dried blood shows an availability of 62 on a basis of 100 for nitrate. From the standpoint of the yield of dry matter, however, dried blood shows a yield of 81 on a basis of 100 for nitrate.

Cylinder Experiments—Series B

It is generally understood that nitrogenous fertilizers may have different effects in different soils. For example, in a heavy clay soil organic materials would decay more slowly than in a light sandy soil, and there is a possibility that in the light soil the loss of nitrate nitrogen through leaching might be greater than the loss of organic nitrogen, even when used in equivalent amounts.

In order that a study might be made of the relative availability of nitrogen in the form of nitrate of soda and dried blood in soils varying in mechanical composition, 60 cylinders were arranged in ten series of six cylinders each and prepared for the growing of crops. All cylinders were filled with a uniform subsoil to within about ten inches of the top, and the soils to be studied were laid on these to a depth of about eight inches. The first six cylinders (Series A) were filled with a loam soil, the second six (Series B) were filled with the same soil containing 10 per cent of coarse white sand; the third six (Series C) were filled with a loam soil containing 20 per cent of the sand, and so on to the tenth series (Series J), which were filled with pure sand (a 60 per cent sand series was not included).

All cylinders receive each year a liberal application of carbonate of lime, acid phosphate, and muriate of potash. Two in each series receive no nitrogen (that is, they are the check cylinders); two receive 10 g. of nitrate of soda, and two receive dried blood equivalent to the 10 g. of nitrate.

A crop of barley and a residual crop of buckwheat are grown each year, all the fertilizers, however, being applied to the first crop. The two crops are harvested and samples analyzed for nitrogen without separating grain and straw. Yields are reported as total dry matter. The results of seven years (1912 to 1918, inclusive) are now available and summarized by averages in Table II. From this summary it will be noted that the yields from the nitrate cylinders are greater than those from the blood cylinders throughout the series until the 100 per cent sand series is reached. Here the lasting qualities of the blood are

shown by a yield of 70.2 g. of dry matter as against 56.7 g. for the nitrate. It is of interest to note that the yields with both materials are well maintained up to and including 50 per cent of sand. Especially is this true of the nitrate as shown by the seven-year average of 155 g. for cylinder F—50 per cent sand—as against an average of 151 g., for the same period, for the four series having 10, 20, 30 and 40 per cent of sand, respectively. The corresponding figures for the blood are 123.2 g. as the seven-year average for the series having 50 per cent sand, and 134.5 g. as an average for the four series having 10, 20, 30 and 40 per cent sand, respectively.

TABLE II

AVERAGE YIELD OF DRY MATTER AND PER CENT NITROGEN RECOVERED ON SOILS VARYING IN MECHANICAL COMPOSITION — 1912–1918. CROPS: BARLEY AND BUCKWHEAT

(1) Yield of Dry Matter—Grams per Cylinder

Treatment	Loam Soil	Per Cent Sand 10	20	30	40	50	70	80	90	100
Nitrate of soda	149	159	146	152	149	155	137	113	104	57
Dried blood	142	148	131	132	127	123	112	110	92	70
Check	80	89	68	67	65	67	47	43	29	18

(2) Average per Cent Nitrogen Recovered

Treatment	Loam Soil	10	20	30	40	50	70	80	90	100
Nitrate of soda	54.8	51.8	57.6	61.2	60.2	61.3	60.4	46.8	50.9	31.8
Dried blood	43.8	45.2	46.0	48.2	45.5	41.2	46.6	48.8	45.1	39.1

Since the yields were greater with nitrate than with dried blood, even where the soil was 50 per cent coarse sand, it seems evident that the loss of nitrate nitrogen must have been less than the loss of organic nitrogen, though we have been accustomed to think that the reverse is true in soils containing considerable sand.

The percentage of nitrogen recovery is well maintained for both nitrate and blood in soil mixtures containing as high as 70 per cent sand. Indeed, where the nitrate was used, the recoveries are higher with 30, 40, 50 and 70 per cent sand than with 10 and 20 per cent sand. Where blood was used, the highest average recovery was with 80 per cent sand and the next highest with 30 per cent sand.

Field Experiment.

In a study of so important a problem, it did not seem wise to rely entirely on cylinder experiments for data, and therefore, in 1908, 40 one-twentieth acre field plots were laid out for use in a detailed study of the relative availability of a number of nitrogenous materials. Since calcium nitrate was claiming attention as a fertilizer at this time, it was included among other materials. The figures reported herewith in Table III are the averages of ten years' results from the sodium and calcium nitrate plots on the one hand, and the dried blood, fish, and tankage (organic nitrogen) plots on the other.

TABLE III

AVERAGE YIELD OF DRY MATTER AND PER CENT NITROGEN RECOVERED —FIELD EXPERIMENTS, 1908–1917

Treatment	Average Pounds Dry Matter per Acre		Per Cent Nitrogen Recovered	
	First 5 Years	Second 5 Years	First 5 Years	Second 5 Years
Nitrate nitrogen, no lime	4191	3432	38.2	31.8
Nitrate nitrogen, with lime	4467	3462	51.0	28.8
Organic nitrogen, no lime	3821	2856	27.3	25.4
Organic nitrogen, with lime	3734	3063	28.5	24.9

A 5-year rotation has been followed, the crops being for the first 5-year period, one year of corn, two years of oats, one year of wheat and one year of timothy. For the second 5-year period the rotation was slightly changed, so that there was only one year of oats and two years of timothy. A careful record has been kept of the total dry matter produced and of the amount of nitrogen applied as fertilizers, and of the amount removed by the crops.

It will be noted that the nitrate plots gave the largest yield of dry matter and the highest recovery in both periods.

If an average is taken of the yields of dry matter from the limed and unlimed nitrate plots and the limed and unlimed organic fertilizer plots, it is found that the difference is close to 500 pounds annually in favor of the nitrate plots for each of the two 5-year periods. The average nitrogen recovery of all the nitrate plots for the ten years is 37.4 per cent, as compared with 26.5 per cent for the organic fertilizer plots.

The reason for the greater effectiveness of nitrate nitrogen than organic nitrogen is not entirely clear, but the residual crop which is grown every year in cylinder experiments (Series B) seems to throw some light on this question. This crop gets practically no benefit from the nitrate—the first crop having utilized practicaclly all that was not lost in some way—whereas it is benefited slightly by the dried blood. In other words, the organic nitrogen does have a slight residual effect, whereas the nitrate has practically no residual effect. However, the initial effect of the nitrate so much exceeds the initial effect of the organic nitrogen that the total recovery is distinctly in favor of the nitrate. **It would appear, therefore, that the nitrate is especially beneficial to the plant in the early stages of its growth at a time when the organic material has not yet become fully effective, and having thus obtained a good start, the plant grows rapidly and utilizes the nitrogen to such good advantage that the loss is really less than from a material that is not so readily soluble. Furthermore, the good start which the nitrate gives the plant enables it to utilize the soil moisture and mineral plant food to better advantage than the plant that starts slower.** [W. P. A.]

Plate I. Lahaina root response to chemical treatment. Figs. 1 and 6, inoculated with **Pythium**, Fig. 1 chemically treated; Fig. 11, uninoculated control 1, untreated.

Plate II. Lahaina root response to chemical treatment. (Duplicate series.) Figs. 7 and 8, inoculated with **Pythium**, Fig. 7 chemically treated. Fig. 12, uninoculated control, untreated.

Lahaina Disease Responds to Chemical Treatment.

By C. W. Cappenter.

In a pot experiment with Lahaina cane recently concluded, evidence was secured which clearly indicates the possibility of controlling the Lahaina disease by chemical treatment. The effect of the treatment on root development was very striking, and while the experiment does not necessarily indicate that the treatment applied is the most practicable one, it does show that chemical treatment has great possibilities. The experiment furnishes a basis for further work, and lends encouragement to the belief in our ultimate success in controlling the disease.* In this note the facts of the experiment are put on record for what they may be worth, field experiments by the writer not yet being started.

A series of twelve Lahaina cane plants were started in steam sterilized soil early in December, 1919. On December 20th six of the plants were inoculated by placing some of the *Pythium* type fungus in the soil. On January 28th three more plants were similarly inoculated. On April 10th, when the disease was well in evidence, 50 cc. of a one per cent. solution of "Qua-Sul"[1] was applied to one pot (9 in. in diameter) of each series of inoculations. The controls, treated and untreated inoculated plants, were watered the same, and otherwise given identical conditions.

The roots of the plants were washed out on May 28th, 1920, with the striking differences in the root systems shown in the plates. This was 48 days after treatment of the two pots when the plants had ceased to develop in the limited soil.

In contrast to the untreated sick plants (Pl. I Fig. 6, Pl. II Fig. 8), whose root systems were limited to a few rotted primary roots, and practically no secondary feeding roots, the plants in the chemically treated soils (Pl. I Fig. 1, Pl. II Fig. 7) showed a remarkable new root system with a considerable quantity of secondary feeding roots. In fact, at the time washed out, these treated plants had a more extensive root system than the control plants in uninoculated soils, which, however, is susceptible of explanation. The uninoculated controls grew normally and exhausted the limited soil available at a relatively early period, after which time the roots gradually crowded each other out and died of impoverishment. The inoculated plants, on the other hand, lost their feeding roots as fast as formed until the chemical treatment was applied. In these pots there was still plenty of room for the development of a good root system as soon as the root parasite was checked by the chemical. In those inoculated pots not chemically treated the root system remained in a crippled condition.

Judging by the meager data thus far obtained, field control and prevention might be possible by applying the "Qua-Sul" to the soil in advance of laying the seed, and to growing cane in advance of irrigation, or applying the material at greater dilution in the irrigation water. The water then could carry the material into the foraging ground of the secondary feeding roots, where it must be to

[1] "Qua-Sul" is a soluble sulphur-carbon compound, manufactured by the A. R. Gregory Company of San Francisco.

check the fungus. Field experiments along the lines indicated have been projected for some time, and their inauguration only awaits the preparation of the soil.

In a similar way the writer demonstrated that repeated irrigation of pots of artificially induced Lahaina disease with 1–50,000 copper sulphate solution checked the disease of the roots, the plants putting out new roots in a normal manner, and the above ground portion of the plant showing improvement. Pot experiments allow only a limited range of observations, and are suitable chiefly as indicators for field experimentation. Such factors as time and periods of application, amounts to apply, as well as the ultimate cumulative effect on future crops, will all have to be taken into careful consideration before such potent chemicals are extensively used.

From our observations on the occurrence of Lahaina disease, and the pineapple "wilt," the most likely time to apply chemical treatments would be in the fall and winter months, when the plants are at the lowest ebb of vegetative vigor, at which times the fungus appears to do the most of its damage. Then treatment, if applied opportunely, would be more preventive than remedial in nature.

ERRATA—April "Record."

On page 28, "Kukuiolono Park," instead of "Kuoolono Park."

On page 22, last line of first article, "universally recognized," instead of "unusually recognized."